CHARACTERIZATION OF DREDGED MATERIAL, LAGUNA MADRE, TEXAS

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1. INTRODUCTION

The Laguna Madre is an environmentally sensitive, ecologically productive coastal water body located behind Padre Island, south of Corpus Christi, Texas This natural system has been altered by many human activities, including the dredging of the Gulf Intracoastal Waterway (GIWW) An Interagency Coordination Team (ICT), consisting of federal and state agencies, was formed to identify environmental concerns regarding the GIWW in the Laguna Madre, and to contribute to a Dredged Materials Management Plan and Environmental Assessment for the GIWW

The U.S Environmental Protection Agency (EPA) is a member of the ICT, and in addition has extensive responsibilities for regulating ocean disposal of dredged materials under the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), as amended. In support of the ICT effort, EPA Region 6 issued Work Assignment 1-05 (Contract No. 68-D6-0067) to its level-of-effort contractor, Lee Wilson and Associates (LWA), and also funded laboratory analyses through the U.S. Army Corps of Engineers, Galveston District (USACE/GD).

Collectively, the work done on behalf of EPA has provided two contributions to the Dredged Materials Management Plan and Environmental Assessment.

- The bulk of the budget resources provided by EPA were used to sample and characterize sediment and water at 26 locations along the GIWW, and at two offshore reference areas where dredged materials from navigation channels are deposited in the vicinity of the Ocean Dredged Material Disposal Sites, or ODMDS.

- A brief report was prepared regarding alternatives for beneficial use of material dredged from the GIWW of the Laguna Madre

This report presents the results of the first study, the characterization of dredged material.

Section 2 of the report summarizes the sampling program conducted by Coastal Environments, Inc (CEI) and the Louisiana Universities Marine Consortium (LUMCON) under contract to LWA

Section 3 summarizes the analyses of the samples, which were performed by independent laboratories under contract to the USACE, using EPA funds Limited data interpretations are presented along with a reporting of statistical results as contracted to Espey, Huston and Associates (EH&A, 1997) and authorized for use in this report by the USACE/GD

Section 4 summarizes the findings of Sections 2 and 3.

Section 5 provides a list of reference documents used

An important aspect of the dredged material characterization effort is that it was a standalone assessment, which provides information from one particular sampling event Integration of this information with the results of prior sampling programs was outside the scope of the work assignment

2. COLLECTION OF SAMPLES

2.1 SURVEY PLAN AND QAPP

The samplıng program was defined ın a Survey Plan whıch was submıtted to and approved by EPA ın May 1997 The plan ıncluded specıfic proposals regardıng sampling locations and methods, which are descrıbed below It also ıncluded a Category II Quality Assurance Project Plan, whıch is provıded as an attachment to thıs report

2.2 SAMPLING LOCATIONS

For this project, a total of 26 samples were collected for sediment, water, and elutriate analysıs wıth sıx of the 26 samples and their locatıons specified by EPA for bioassays. These sites were dıstributed along the length of the GIWW ın the Upper Laguna Madre (ULM) and Lower Laguna Madre (LLM) The selectıon of specıfic sites reflected locatıons of anticıpated future dredging, potential for contamınation, past and ongoing samplıng efforts by others, potentıal locatıons for the beneficıal use of dredged material, and a general effort to spread the sites ın geographically representative areas along the entıre 117-mile reach of the GIWW which occurs ın the Laguna Madre

The sampling sıtes are shown on Fıgure 1 and lısted in Table 1. The dıvısion of the GIWW used for revıew of water and sedıment qualıty data from varıous federal and state agencies (EH&A, 1996) has been maintaıned for geographıc reference purposes Indıvidual segments of the GIWW were labeled ULM0 through ULM19 for the Upper Laguna Madre from Corpus Christı Bay through the Land Cut, and LLM20 through LLM37 for the Lower Laguna Madre from the Land Cut to Port Isabel Locatıons of the samplıng sıtes ın Table 1 were expressed ın terms of the numbered segments LLM and ULM, as well as the distance in feet along the GIWW as measured from Corpus Chrıstı Bay for the Upper Laguna Madre, and from Port Isabel for the Lower Laguna Madre The latter geographıc referencıng corresponded to the dredged materıal database of the USACE/GD The ın-channel samplıng statıons wıthin each segment were then denoted as either LM or BA, wıth the latter sıgnıfying bıoassay sample collection

The Survey Plan set forth a ratıonale for the selectıon of specıfic sıtes. That dıscussıon ıs provıded below (Sectıons 2 2 1 - 2 2 3), as a reference for those not having access to the orıgınal plan

2.2.1 Representation of dredged material

Because of variation in geographic setting of the GIWW, and related variation in hydrodynamic conditions, sedimentation in and historic maintenance dredging of the GIWW vary greatly along the waterway In order to achieve the most accurate representation of the areas where dredging was most likely to occur, the maintenance dredging records from 1946 through 1995 were reviewed for the entire GIWW portion to be sampled The review of dredging operations was done jointly with the USACE/GD personnel, using the USACE's database The database provides the year and quantity dredged by approximately one-mile sections

In the ULM, the dredging operations database showed frequencies and quantities of dredging as follows

High frequency and quantity:

- between Corpus Christi Bay and the JFK Causeway (ULM0)
- from the center of Baffin Bay southward to the Middle Ground (ULM9, 10 and 11)

Medium frequency and quantity

- from Green Hill to the center of Baffin Bay (ULM7 and 8)

Low frequency and quantity:

- JFK Causeway to Green Hill, including Bird Island area (ULM1 through ULM6)
- Middle Ground through the Land Cut (ULM12 through ULM19)

In the LLM, the dredging operations database showed the following distribution of frequencies and quantities of dredging:

High frequency and quantity:

- south end of Land Cut (LLM20)
- vicinity of Port Mansfield Channel intersection (LLM25,26)
- Arroyo Colorado Cutoff intersection (LLM30)
- Cheryl Shoal, lower LLM (LLM34, 35)

Medium frequency and quantity:

- south end of Land Cut to near Port Mansfield Channel (LLM21 through LLM24)
- Port Mansfield Channel to North Floodway (LLM27)
- Arroyo Colorado intersection to north end Cheryl Shoal (LLM31 through 33)

Low frequency and quantity:

- south of Port Mansfield channel to Arroyo Colorado (LLM27, 28 and 29)
- south end Cheryl Shoal to Port Isabel (LLM36 and 37)

2.2.2 Known and potential areas of contamination

Several federal and state agency databases concerning water and sediment quality in the Laguna Madre were recently analyzed for geographic and temporal trends in these parameters (EH&A, 1996) This analysis revealed a number of areas where metals and/or organic pollutants showed elevated concentrations or were potentially of concern Water quality data gave reason for concern at the Arroyo Colorado and North Floodway because of elevated arsenic and silver concentrations Elevated metals concentrations were found at segment LLM33, but derived from a single sampling event in 1987 Similarly, a single sampling event had indicated high metal values at LLM37 in 1980.

Sediment quality analysis for the Upper Laguna Madre indicated highest mean concentrations for metals, with the exception of nickel, at segment ULM10 near Baffin Bay; concentrations of nickel were found to be highest in ULM11. In the Lower Laguna Madre, spatial analysis for zinc in elutriate analyses revealed the highest mean concentrations at segments LLM24 and 25, near the Port Mansfield channel Elevated concentrations were not confirmed, however, by sediment and water samples in that area. Elevated metal concentrations were found furthermore in sediment samples from segment LLM37, near Port Isabel

Water and sediment quality data appeared to be generally inconclusive with regard to site-specific concerns and spatial or temporal trends. Sampling in inland water bodies, hydrologic connections to coastal uplands, and navigation routes did, however, point toward potential areas of contamination. These areas included the major navigation channels of Port Isabel and Port Mansfield, the connection to Corpus Christi Bay; mineral industry activities in upper Laguna Madre near the Bird Islands; and connections via Baffin Bay, Arroyo Colorado, and the North Floodway to upland development Sediment data from TNRCC's 305(b) report were used to identify concerns near the Bird Islands in ULM.

2.2.3 Sampling sites

The Environmental Protection Agency specified six general areas at which samples for bioassay analysis were to be obtained These reflected, generally, the concern for known or potential contamination as mentioned above Specific locations for these sites were developed by further taking into consideration past dredging activities The six sites were positioned within the areas specified by EPA at locations where dredging of material is required most frequently because of shoaling. Where dredging has occurred regularly over a distance of several miles, the site for bioassay samples was located in the central portion of the reach. These sites are listed in Table 1 as BA1 through BA6 and are located as follows: 1) along the GIWW near the connection of Upper Laguna Madre and Corpus Christi Bay; 2) near North Bird Island; 3) at the Port Mansfield Channel, 4) near the primary natural outlet channel of the North Floodway; 5) near the mouth of Arroyo Colorado; and 6) near Port Isabel.

Several objectives guided the selection of the remaining 20 sampling sites. These were: 1) to bracket the most heavily dredged reaches of the GIWW; 2) to bracket areas of greater concern and higher probability should contaminants be present at elevated levels; and 3) fill information gaps to the extent feasible. The locations of these 20 sampling stations, LM-1 through LM-20, are given in Table 1, using both the ULM and LLM segment-reference and the USACE/GD distance-along-GIWW reference. The rationale for individual sampling sites is presented summarily in Table 2 from Corpus Christi Bay southward to Port Isabel.

For reference purposes, EPA specified two additional sampling sites. These were the Reference Material Collection Sites associated with the Port Mansfield Ocean Dredged Material Disposal Site (ODMDS) and the Brazos Island Harbor (BIH) ODMDS, identified as REF1 and REF2, respectively (see also Figure 1, Table 1) Both sites were located in the Gulf of Mexico, on the updrift (south) side of the deep water navigation access channel, approximately 2 miles offshore. Corner latitudes and longitudes are specified for each of these two areas in the Regional Implementation Agreement (RIA) between EPA Region 6 and the USACE/GD for the Texas coast Also included in this document are data from the most recent sampling of the Corpus Christi ODMDS reference control site (CCREF) by Espey, Huston & Associates (1995b)

2.3 SAMPLING METHODS

The work assignment required that samples be taken of both bottom sediment and water Sampling methods followed the requirements of the "Evaluation of Dredged Material Proposed for Ocean Disposal Testing Manual" (Green Book) and the RIA (Table 10)

Field measurements were made on the following parameters at each sample site using a Hydrolab SVR3 and YSI Model 30 instrumentation· salinity, water temperature, pH, and dissolved oxygen (DO) Turbidity was also recorded using a secchi disk

At each sampling site, the location and depth readings were fixed via a differential global positioning system (DGPS) receiver and fathometer on the sampling vessel. The vessel was maneuvered to the centerline of the channel then to each side from a secondary wheelhouse located on the rooftop Sediment samples of the bottom material were taken with a gravity-driven stainless steel box corer (Figure 2) No samples were taken below the normal depth of dredging. The sediment samples were on-deck composites of material from the two sides and center of a given channel site.

In-channel sediments for chemical analysis were scooped from the center of the coring unit with a Teflon-coated spatula into a stainless steel bowl, which was filled to about one-third capacity at each of the three sites. This provided the composite sample which, in turn, was homogenized with the spatula and transferred into laboratory-supplied clean glass containers that were overfilled to exclude air. Each container was capped with a Teflon-lined lid before storage on ice to 4°C

In-channel sediments for bioassay/bioaccumulation work were collected from the mid channel with the box corer and scooped with a non-contaminating shovel into 26 L polyethylene containers that were sealed air-tight and stored at 2 to 4°C within 24 hours of sampling until analyzed. For each Reference Site, sediment samples were composited from three locations that were determined by dividing each Reference Site into three equal areas and designating the center of each area as the sampling location The latitude/longitude coordinates provided in the RIA provided the basis for determining each location, which was entered as a waypoint in the vessel's DGPS for navigating purposes

Water samples were obtained from about 3 feet below the surface using a peristaltic pump fitted with Teflon tubing (Figure 2) Salinity stratification was not observed, thus negating the need for taking near bottom samples as described in the Survey Plan Water-column samples at the Reference Site were on-deck composites from the same sites as the sediment samples At other locations, the water sample was taken from the channel centerline as per the sampling guidelines in Work Assignment 1-05 At all locations, the water sampling preceded the sediment sampling and consisted of filling each laboratory-supplied container to maximum capacity to eliminate headspace before capping with a Teflon-lined lid and storage on ice to 4°C.

Precautions were taken to avoid contamination of the samples by wearing new latex gloves and decontaminating reusable equipment with a soap, solvent, and deionized water rinse at each site In addition, as a quality control measure, replicate water quality samples at two sites (BA5 and BA6) were taken using ultraclean techniques. Specific measures utilized for these samples that were not used for the conventional water samples included the use of new, decontaminated hose for each set of ultraclean samples and the sampling (container uncapping, filling and capping) conducted by one individual only to eliminate the possibility of cross-contamination.

The media, analytes and sample requirements are summarized as follows:

Media	Analysis	Containers	Capacity (ml)	Preservatives
water	Metals	one (1)	500 plastic	HNO_3
	pesticides/PCB	one (1)	1000 amber glass	none
	PAH/phenols	one (1)	1000 amber glass	none
	TOC/NH3	one (1)	500 amber glass	H_2SO_4
	TPH	one (1)	1000 amber glass	H_2SO_4
water	Elutriates	six (6)	1000 amber glass	none
sediment	all analytes	two (2)	1000 clear glass	none
sediment	Bioassay	five (5)	26 liter polyethylene	none

Table 3 lists the parameters for chemical analysis with their corresponding detection limits and EPA analytical methods. The primary constituents included. metals, pesticides/PCBs, PAHs, as well as some additional analyses cited in Table 2 of the RIA.

2.4 IMPLEMENTATION

Sampling was conducted by personnel from Coastal Environments, Inc., Espey, Huston & Associates and the Louisiana Universities Marine Consortium (LUMCON) from the *R/V Acadiana*, a research vessel owned and operated by LUMCON and docked in Cocodrie, LA. Features of this vessel included:

- 58 foot length, 18 foot width, 4 foot draft
- A-frame and three winches (trawl, electromechanical, hydraulic)
- large open deck for sampling work
- 144 square-foot laboratory on board
- on-board electricity and cooling/freezing capabilities
- differential GPS, depth sounding
- on-board quarters, to enable long sampling days

The Survey Plan outlined a possible sequence of sampling sites, with the provision that actual sites would be sampled in accordance with field judgments. In practice, the sites were sampled as follows

DATE	SITES
June 5, 1997	LM-4, LM-3, BA2, LM-2, BA1, LM-1
June 6, 1997	LM-10, LM-11, LM-12, LM-13, LM-14
June 7, 1997	REF1, BA6,
June 8, 1997	REF2, LM-20, LM-19, LM-18, LM-17, BA5, LM-16, BA4, LM-15
June 9 1997	LM-9, LM-8, BA3, LM-7, LM-6, LM-5

Latitudes and longitudes for all sites were determined prior to vessel departure using USACE/GD distances along the GIWW designations, and Intracoastal Waterway Nautical Charts, within a Geographic Information System (GIS) framework Site locations aboard the vessel were determined using the DGPS All GIWW and offshore site locations were also referenced to the nearest navigation marker.

Because sediments used for bioassays needed to be in the laboratory within 24 hours of collection, the preserved samples were brought to shore at the following locations and dates, and immediately transported to the laboratory by special van: Corpus Christi (June 6, 1997), Port Mansfield (June 8, 1997), and Corpus Christi (June 10, 1997) The remaining sediment and water samples were packed in ice to 4 ^{o}C and stored in ice chests for shipment to the laboratory

3. RESULTS AND INTERPRETATIONS

3.1 ANALYSES, GOALS AND CRITERIA

Analyses performed and goals. The objective of the analyses conducted was to obtain a set of measurements representative of the physical and chemical characteristics of the environments of interest, from which inferences could be made regarding the impact of dredged material deposition on the benthic environment and the water column The emphasis was on the collection of representative sediment and water samples for chemical analysis, bioassays, and bioaccumulation tests

The following analyses were performed on sediments and water samples

- physical analysis of sediment
- bulk chemistry analysis of sediment
- chemistry of water
- chemistry of elutriates
- sediment toxicity
- bioaccumulation

The laboratory work included screening for the following.

- total volatile solids
- percent total solids
- metals
- grain size distribution
- total organic carbon
- total petroleum hydrocarbons
- sulfides
- phenols
- PCBs and pesticides
- ammonia, for six samples used in the bioassays

The sediment and water samples were required for several purposes.

- evaluation of dredged material for disposal
- characterization of the disposal area for potential impacts on existing resources and habitats
- determination of sedimentary and hydrologic characteristics related to habitat development or enhancement

Criteria. Water and elutriate analysis results were compared to EPA Marine Water Quality Criteria (WQC) to identify any values higher than the published criteria. Sediment analysis results were compared to available guidelines (e.g Long et al., 1995), as no EPA criteria are available. Bioassessment evaluations were based on a comparison of surviving sensitive benthic organisms in sediment from a potential dredge location to those in sediment from reference locations (ODMDS sites). For the toxicity bioassay, statistical comparisons of mean survival were made for each species if the mean survival for any station test was less than that of the average of the reference samples, and there was greater than 10% difference between mean reference and test survival (20% for amphipods) For the bioaccumulation assessment, statistical comparisons of mean concentrations were made for each parameter and species if the mean concentration of the parameter for any station exceeded that of the reference sample.

3.2 PHYSICAL PARAMETERS

The sediment and water sampling at each site was preceded by a series of physical measurements which included: dissolved oxygen (DO) in milligrams per liter (mg/l), pH, salinity in parts per thousand ($^{0}/_{00}$), water temperature in degrees centrigrade (^{0}C), and turbidity (secchi disk) in feet. The results are presented in Table 4. Results for grain-size analyses of sediment samples are presented in Table 5.

The surface water sample depth corresponds to the 3 ft reading listed under the heading "sample depth" in Table 4 The GIWW sediment sampling was conducted in relative water depths ranging from 10.3 to 20 1 feet, and averaging 15.5 feet The two offshore reference sites (REF1 and REF2) were sampled in relative water depths of 45 and 47 feet, respectively (Table 4). DO readings, for all stations, ranged from 2 75 to 7 64 mg/l, averaged 5.62 mg/l, and decreased with depth The lowest concentration occurred at LM-5, north of Baffin Bay. pH values averaged 8.52 and ranged from 8 02 to 8.94. Overall, salinities ranged from 23.5 to 40 1 $^{0}/_{00}$ and averaged 31.4 $^{0}/_{00}$ The readings did not vary markedly at each site The highest salinity was observed in the ULM at BA-2, near the Bird Islands. Water temperatures ranged from 21.7 to 29 8 ^{0}C and averaged 27 7 ^{0}C

The sediment composition is primarily silt and sand size particles averaging 0 08 millimeters (mm) and ranging from 0 01 to 0 21 mm The finer sediments occur between LM-5 and LM-9 in the lower half of the Upper Laguna Madre, and between LM-11 and LM-15 in the upper half of the Lower Laguna Madre (see Table 5).

3.3 SEDIMENT CHEMISTRY

3.3.1 Data

In addition to the physical parameters, analysis of sediments also included testing of metals, total solids and volatile solids, sulfides, ammonia (as N), TOC, TPH, phenols, PCBs, and pesticides based on composite samples collected from the GIWW and reference sites TOC was analyzed by Method 413.2, an oil and grease determination with a method detection limit of 5 0 mg/kg (not by Method 9060) For only one sample, LM1, was TOC detected in the sediment (7 2 mg/kg). The TPH, phenols, PCBs, and pesticides analyses were below detection limits in all sediment samples Table 6 presents results of the chemical analyses for parameters above detection limits (for metals, total sulfide, ammonia-N, total and volatile solids), as well as sediment particle size distributions

Metals were detected at all sample locations; however, all ten metals were found only in samples from LM-8, LM-10, and BA-6. In general, the highest concentrations of most metals occurred at stations with a predominantly silt/clay (i.e., fine-grained) sediment type, especially at the mouth of Baffin Bay and south toward the Land Cut (LM-6 through LM-9) LM-6 had the highest concentration of five of the ten metals (chromium, copper, lead, nickel and zinc), while LM-8 had the highest concentration of two other metals (barium and cadmium). Ammonia-N and total sulfide were detected in all channel and reference sample locations LM-2 had the highest total sulfide concentration at 488 mg/kg, and LM-9 had the most ammonia at 378 mg/kg. In general, the higher ammonia-N and total sulfide concentrations were associated with the Baffin Bay area of the ULM (LM-4 through LM-9).

Arsenic was found above detection limits at all locations, but occurred in high concentrations only at LM-11 (583 mg/kg) and BA-6 (383 mg/kg) Cadmium also occurred in high concentrations in sediments from two locations, LM-8 (40 mg/kg) and BA-4 (10 mg/kg). Mercury was detected at seven stations, with the highest concentrations occurring at LM-8 (0.23 mg/kg) and LM-12 (0 17 mg/kg). TOC was found at 7.2 mg/kg (using Method 413.2) at LM-1

3.3.2 Interpretations

There are no U.S. Federal or state sediment criteria with which to compare the metals data, but federal or international guidelines do exist (e.g , Long et al., 1995) The Effects Range Low (ERL) and Effects Range Medium (ERM) guidelines developed by Long et al (1995) for inorganics in marine environments were used to evaluate Laguna Madre sediment chemistry results (see Table 6) The ERL and ERM were determined for individual compounds to define three ranges of sediment contamination. The ERL was defined as the concentration associated with the 10th percentile of the effects data for a compound and the ERM was defined as the concentration associated with the 50th percentile of the effects data Concentrations below the ERL are expected to predict conditions under which adverse biological effects would occur rarely (a minimal effects range) Concentrations between the ERL and ERM values fall in a possible effects range, in which adverse biological effects would occasionally be observed. Concentrations above the ERM represent a probable effects range, where negative effects would be expected to occur frequently.

The concentrations of arsenic observed in sediments from stations LM-11, LM-14 and BA-6 substantially exceed the ERL of 8 2 ug/g. Similarly, the sediment concentrations of cadmium at stations LM-8 and BA-4 exceed the ERL of 1.2 ug/g. The sediment concentrations of mercury at stations LM-8 and LM-12 slightly exceed the ERL for mercury of 0.15 ug/g. Two of the arsenic and one cadmium value also exceed the ERM guidelines from Long et al. (1995), while both values for mercury do not. Thus, the two mercury values with low exceedances suggest the potential only for occasional or possible effects, while the three arsenic and two cadmium values are in a range that suggest probable effects. Based on this evidence, arsenic and cadmium in sediments from LM-8, LM-11, LM-14, BA-4, and/or BA-6 could represent cause for concern.

Pyrene was found in sediments from LM-4 at 84 μg/kg, while benzo(e)pyrene (105 μg/kg), pyrene (114 μg/kg), benzo(a)anthracene (56 μg/kg), benzo(b)fluoranthene (111 μg/kg), and benzo(k)fluoranthene (134 μg/kg) were detected at BA-6 The high total sulfide and ammonia-N concentrations at LM-4 do not correspond with the lack of TOC. This lack of TOC may be due to Method 413 2, which does not render decaying plant material readily extractable, but the presence may be inferred by the percent volatile solid concentrations ranging from 1.11 to 5 32 mg/kg versus a detection limit of 0.1 mg/kg.

3.4 WATER AND ELUTRIATES

3.4.1 Data

The water sampling component included the collection of individual in-channel and reference composite samples that were analyzed for metals (500 ml sample volume), pesticides/PCBs (1000 ml sample volume), phenols (1000 ml sample volume), total petroleum hydrocarbon (TPH) (1000 ml sample volume), total organic carbon (TOC) (500 ml sample volume), and elutriates (6,000 ml sample volume) Among the suite of samples, two ultraclean samples were collected at BA-5 and BA-6.

Tables 7 and 8 provide the results for water and elutriate samples that showed detectable levels of these analytes for at least one station (total petroleum hydrocarbons (TPH), arsenic, barium, cadmium, chromium, copper, lead, and zinc) TPH was found in 5 water (LM-7, LM-15, LM-16, LM-20, BA-5) and 5 elutriate (LM-4, LM-7, LM-10, LM-15, LM-20) samples. Highest concentrations occurred in water at LM-7, near Baffin Bay (5,400 µg/L) and in elutriate at LM-15, near the North Floodway (1,160 µg/L) However, concurrent ultraclean sampling of water at BA6 resulted in no detection of TPH, suggesting that at least some of these detections of TPH may represent sample contamination. No other concentrations of organics were found in the samples.

Arsenic concentrations were detected in all but two water samples and in all elutriates Elutriate concentrations exceeded water concentrations for all stations. The highest elutriate values of 17.9 to 18.5 mg/l occurred at in the Upper Laguna Madre at LM-6, 7, and 9 The range of values in the elutriates (1.6 - 18.5 µg/L) is well below the marine acute (69 µg/L) and marine chronic (36 µg/L) WQC provided by the EPA for the protection of aquatic life

Barium was detected in all water and elutriate samples As with arsenic, barium concentrations in the elutriates were numerically higher than those in the water for all stations but LM-16. There are no federal or state standards for barium, but the Gold Book Criterion (EPA, 1986) is 1,000 µg/L barium for domestic water supply. The only value to exceed 1,000 µg/L barium was the LM-5 elutriate value of 1,320 µg/L. Cadmium was also detected at most stations, with the highest values occurring in water samples from BA-1, LM-12, and LM-14, and in elutriate samples from LM-5, LM-12, and BA-4 The ratio of cadmium concentrations in water versus elutriates ranges from 7 5 (at BA-4) to 6.3 (at LM-4). There was no apparent trend to the numerical changes in cadmium concentrations nor in the ratios of cadmium in water versus elutriates. The EPA marine acute and marine chronic criteria for cadmium were not exceeded at any station

Chromium concentrations in both water and elutriates included large station-to-station variability with no apparent trends. The highest water concentration was found at LM-2 (27.8 µg/L), while the highest elutriate concentrations were found at LM-4 (10.7 µg/L) and LM-11 (10 6 µg/L) Chromium concentrations in elutriates were numerically higher than those in the water for most stations, except LM-1, BA-1, LM-2, LM-3, and BA-6 Although there are no EPA Marine Water Quality Criteria for total chromium, the criteria for hexavalent chromium of 1,100 µg/L acute and 50 µg/L chronic were not exceeded

The EPA marine chronic and acute criteria (2.9 µg/L) for copper were exceeded at all 28 stations in water samples and all but one station in elutriate samples, with LM-2 the exception The highest water and elutriate concentrations of copper were 33.3 µg/L at LM-2 and 25.5 µg/L at LM-6, respectively EPA's marine criteria for copper, unlike other metals, are significantly more stringent than the Texas marine criteria· acute = 2.9 vs 16.27 ug/l, chronic = 2 9 vs. 4.37 ug/l, respectively. Using the Texas standards, most stations would still exceed the chronic criterion, but not the acute criterion The ratio of copper concentrations in elutriates versus the water varied from an increase by a factor of 3 4 for REF1 to a decrease by a factor of 12.8 at LM-2 Copper is discussed further below

Lead was detected in all but 8 water and all but 9 elutriate samples. The highest concentrations exceeded the EPA marine chronic WQC of 5 6 µg/L and were found in water at LM-2 (7.49 µg/L) and LM-11 (6 80 µg/L), and in elutriate at LM-2 (22 60 µg/L) and BA-4 (7 5 µg/L) No samples exceeded the EPA marine acute WQC of 140 µg/L The lead ratio of concentrations in elutriates versus water varied and no trends were evident

Zinc was detected in all water samples and all but one elutriate sample (LM-17) The EPA marine acute (95 µg/L) and chronic (86 µg/L) criteria for zinc were exceeded only in the water samples near the mouth of Baffin Bay at LM-6, BA-3, LM-8, and LM-9, and also in the lower lagoon near the mouth of North Floodway at LM-16. The zinc concentrations ranged from 133 to 415 µg/L for those stations.

Overall, four of the seven metals had the highest concentrations in water samples from LM-2.

3.4.2 Interpretations

Exceedances of the EPA WQC for metals in water represent a potential concern separate from the consideration of any potential concerns associated with dredging and disposal or beneficial use of sediments. The exceedances of EPA acute WQC for copper and zinc in water samples and for copper in elutriate samples indicates a potential cause for concern Using the tiered approach in the Green Book, this potential concern is addressed by determining whether the limiting permissible concentration (LPC) can be met by dilution. The LPC for copper in water and elutriate samples cannot be met, since the background concentration, estimated as the average of the values from REF1 and REF2 (9 4 µg/L), also exceeds the acute WQC of 2.9 µg/L

The high levels of copper at all locations raise the possibility that the water column in the channel may have exceeded the assimilative capacity for copper However, research related to copper suggests that, because of sampling and analytical difficulties, apparent high levels of copper are not certain indicators of a water quality problem in Laguna Madre Rather, they indicate a need for further investigation, and a need for ultraclean sampling using the latest methods from USGS for the most accurate estimates of dissolved (rather than total) concentrations For additional discussion of this subject, refer to the companion report to this one, entitled Alternatives for Beneficial Use of Dredged Material, Laguna Madre, Texas, Section 3 4 1, "Characteristics of Dredged Material"

As with sediment, most of the stations exceeding zinc and lead criteria were in the vicinity of Baffin Bay and south toward the Land Cut. Another was in the Lower Laguna Madre at LM-16, between the North Floodway Outlet Channel and Arroyo Colorado These exceedances may reflect runoff from mainland sources (see discussions in Alternatives for Beneficial Use of Dredged Material, Laguna Madre, Texas, Section 2 2, "Characteristics of Dredged Material") Note that all metals measured in water samples are total, not dissolved, concentrations, while metals measured in elutriate samples are dissolved concentrations because of the elutriate preparation methodology (EHA, 1998) Therefore, minor apparent exceedances of criteria in water samples may not be exceedances in fact, as the criteria are for dissolved concentrations.

3.4.3 Ultraclean samples

The results from the ultraclean methods employed at BA-5 and BA-6 exhibited only one apparent difference from the regular sampling methods (Table 7). A detected TPH concentration of 200 μg/L in BA-5 appeared as a not detected in the ultraclean result, based on a detection limit of 100 μg/L This suggests that the detection of petroleum hydrocarbons in the regular water sample may represent contamination. Petroleum hydrocarbons are relatively ubiquitous, and under regular sampling protocols, avoidance of contamination can be difficult Otherwise, the remaining concentrations were neither consistently higher nor lower for either method.

3.5 BENTHIC TOXICITY TESTS

3.5.1 Data

Two crustaceans, the amphipod *Ampelisca abdita*, and the grass shrimp *Paleomonetes pugio*, were used in 10 day solid phase toxicity bioassays according to the RIA and Green Book The purpose of this testing was to determine if dredged material is significantly more acutely toxic to *A abdita* and *P pugio* than are sediments from reference area(s) Tables 9 and 10 present the results from these solid phase bioassays for the ULM and LLM, respectively, based on the number of surviving amphipods and grass shrimp out of 100, the average survival per sample, and percent survival. The ranges of physical parameters measured during these tests and results of statistical analyses are included in Appendix A Note that for the solid phase bioassay tests, the EH&A (1998) laboratory comparison of dredged materials to reference area sediments was only for the two reference areas in Lower Laguna Madre, and did not include comparison to Corpus Christi reference site sediment results However, the Corpus Christi results are listed for comparison in Table 9, "Benthic results, Upper Laguna Madre"

In the Upper Laguna Madre, survival in test sediments was not lower than survival in reference sediments for either species tested (Table 9). In the Lower Laguna Madre, survival of *P pugio* was also not lower in sediments from any test station compared to survival in reference sediments (Table 10). However, survival of *A. abdita* in test sediments was lower than survival in reference sediments for all three stations tested (BA4, BA5, BA6) (Table 10) However, this difference was significant (based on the Bonferroni t-test) only for BA-4, where the difference in mean survival between the reference and test sediments was slightly greater than 20% (Table 10; Appendix A, Table A-2) The LPC for benthic toxicity is not met because of the significant toxicity effect at station BA-4.

3.5.2 Interpretations

The solid phase toxicity bioassay results indicate that, except for sampling station BA-4 (North Floodway Outlet Channel), there appears to be no potential for environmentally unacceptable lethal impacts on benthic organisms from the disposal of any ULM or most LLM sediments.

The significant toxicity effect on *A. abdita* exposed to sediment from BA-4 suggests a potential for placement of dredged material from the vicinity of BA-4 to impact benthic organism survival This would lead to a conclusion that material removed from that reach may not be suitable for disposal at the offshore sites However, the results for BA-4 are only marginally significant, and it would be prudent to consider further testing of sediments from this area before final disposition of any dredged material from this area is determined. Espey, Huston and Associates (EHA, 1998) point out that the difference in survival between sampling station BA-4 and the reference controls was 20.5%, only marginally above the cutoff value of 20%. Also, survival of *A abdita* was low in sediments from REF2 (Brazos Island Harbor ODMDS) and all of the Lower Laguna Madre stations, and the difference between the tabulated and calculated t-values was small.

3.6 TISSUE BIOACCUMULATION

3.6.1 Data

The polychaete *Nereis virens* and the mollusc, *Macoma nasuta,* were the two organisms analyzed in 28-day bioassays for bioaccumulation assessment. One purpose of these tests was to determine if concentrations of contaminants in tissues of test organisms exceeded FDA action levels for those contaminants after 28 day exposure to the test material to be dredged and deposited offshore. A second purpose of these tests was to determine if concentrations of contaminants in tissues of test organisms exposed to dredged material were greater than those in tissues of organisms exposed to reference sediments Tissue samples were analyzed only for parameters listed in Table 8 of the RIA. Tables 11 to 14 report the concentrations in tissues of all analytes found above detection limits in at least one sample. As with toxicity bioassays, the EH&A (1998) laboratory comparison of dredged materials to reference area sediments was only for the two reference areas in Lower Laguna Madre, and did not include comparison to Corpus Christi reference site sediment results. However, the Corpus Christi results are listed for comparison in Tables 11-14 Table 3 lists all the analytical parameters measured and their respective detection limits. The following discussion is excerpted, with modification, from a USACE/GD document prepared by EH&A (1998).

No organic chemicals were found above detection limits in test organism tissues. The metals arsenic, barium, chromium, copper, lead, nickel, and zinc were found in tissue samples above detection limits. Silver was detected only once at 0.10 mg/kg versus a detection limit of 0.10 mg/kg, in one replicate of *N. virens* exposed to BA-6 sediment, but these data were not subjected to statistical analysis, and were not included in Table 12. The range of physical parameters in the 28-day study is listed in Appendix B (Table B-1). The ULM and LLM test stations for *N. virens* were compared to the combined mean of both REF1 and REF2 because the tests were conducted simultaneously with the same group of organisms The ULM test stations (BA-1, BA-2, and BA-3) for *M nasuta* were compared to REF1 while the LLM test stations (BA-4, BA-5, and BA-6) for *M nasuta* were compared to REF2 because the tests were conducted on separate dates and with separate groups of organisms

Tissue concentrations of arsenic in *N virens* from test sediments never exceeded tissue concentrations of *N virens* exposed to reference sediments (Tables 11 and 12) The concentrations of barium in tissues of *N virens* from BA-1, BA-5, and BA-6 were significantly higher than for *N. virens* from reference sediments (Tables 11 and 12, Appendix B, Tables B-2 and B-6), but were not significantly different than the concentration of barium in *N virens* archive tissue, representing the background concentrations occurring in the test organisms (Appendix B, Tables B2a and B6a) Chromium in tissues of *N virens* was significantly higher for BA-5 than for reference sediments (Tables 11 and 12, Appendix B, Tables

B-3 and B-7), but again, was not significantly higher than background tissue levels (Appendix B, Tables B3a and B7a) The mean concentrations of barium in tissues of *M nasuta* exposed to sediments from BA-1 were significantly higher than the mean concentration in clams exposed to reference sediments (Appendix B, Tables B-10 and B-12).

For barium, there is no FDA action level with which to compare results. In most natural waters, there is sufficient sulfate or carbonate to precipitate any barium present in the water as a virtually insoluble, non-toxic compound (EPA, 1986). Recognizing that the physical and chemical properties of barium generally will preclude the existence of the toxic soluble form under usual marine conditions, a restrictive criterion for aquatic life appears unwarranted (EPA, 1986) As with barium, chromium has no FDA action level, because chromium is necessity to the human diet and has low toxicity (Kramer, 1994)

The Green Book (Section 6.3) and the RIA indicate an initial evaluation and decision point if bioaccumulation concentrations of contaminants are detected in tissue samples. First, tissue concentration results are compared to FDA action levels.

- If the concentrations are significantly greater than FDA action levels, the LPC for bioaccumulation is exceeded.

- If the concentrations are not significantly greater than FDA action levels or there are no FDA action levels, there is insufficient information to determine if the LPC for bioaccumulation is exceeded, and the next decision point must be considered

In the latter case, the tissue concentrations of organisms exposed to test sediments and reference sediments are compared statistically. This is referred to as Factor 1 in the RIA

- If there is no significant difference, the LPC is not exceeded

- If the test tissues contain significantly greater concentrations than the reference tissues, then additional factors are assessed by the EPA and USACE to evaluate the LPC on a case by case basis.

These additional factors are referred to as Factors 2 through 9 in the RIA The RIA notes that the EPA and USACE will evaluate Factors 1-4 first and if a determination on the LPC cannot be reached at that point, Factors 5-8 will be evaluated If a compliance decision still cannot be reached, a sampling plan will be developed and agreed upon by the EPA and USACE to address Factor 9

Factor 2 Magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material

The means of barium in *N virens* tissues for which significance was determined varied from 0.692 mg/kg to 2 028 mg/kg, compared to means of 0.368 mg/kg and 0.532 mg/kg for the reference control and background tissue samples, respectively. Only the value of 2 2028 mg/kg at station BA-5 differs from the reference value by more than a factor of 1.3 The mean for barium in *M nasuta* tissues at BA-1 was 2 518 mg/kg, which was significantly different from the reference control mean of 1.518 mg/kg by a factor of 1.66. Thus, the observed levels of difference are not very large The mean for chromium in *N virens* tissues for BA-5 of 0 264 mg/kg, which was significantly different from the reference control mean of 0.181 mg/kg, only differed from the reference mean by a factor of 1 46 In addition, the background tissue mean was higher, at 0.311 mg/kg. FDA levels of concern for chromium for edible shellfish range from 11-13 mg/kg, which are levels much higher than observed in these bioaccumulation tests

Factor 3 Number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

Only two (nontoxic) contaminants were accumulated from the 49 for which analyses were conducted

Factor 4 Number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

One of two species exhibited accumulation of chromium, both species exhibited accumulation of barium. However, only barium in *M. nasuta* tissues was significantly greater than both reference control tissues and background sample tissues.

Factor 5 Toxicological importance of the contaminants whose bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material

As noted in Section 3 3 1, barium and chromium do not have FDA action levels because (1) the physical and chemical properties of barium generally preclude the existence of the toxic soluble form, and (2) chromium is essential to the human diet and exhibits low toxicity Additionally, a barium compound solution is ingested by persons before gastrointestinal tract x-rays

Factor 6 Phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material

The burrowing polychaete, *N. virens,* exhibited bioaccumulation compared to the reference control but not background samples, while the filter-feeding clam, *M nasuta,* exhibited bioaccumulation of barium at one station relative to both.

Factor 7 Propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs

Significant biomagnification of chromium and barium is not likely. F Prosi (in Forstner and Whitman, 1979) states, "Detritus-, sediment-, and filter-feeding organisms could be affected by heavy metals occurring in their environment. Nevertheless, these organisms apparently only transfer a small amount of their metal content to the higher levels of the food chain .." Prosi presents biomagnification factors of only 1.4 to 1.9 for lead from sediment-associated benthos to carnivorous nekton. No numbers are presented for barium or chromium.

Factor 8 Magnitude of toxicity and number and phylogenetic diversity of the species exhibiting greater mortality in the dredged material than in the reference material.

As noted in Section 3.3.1, no toxicity was observed for the grass shrimp, *P. pugio,* or for the polylchaete *N. virens* used in the bioaccumulation tests. A marginal level of toxicity was observed for the burrowing amphipod, *A. abdita,* at only one of the six stations tested. Reduced survival was observed at test stations compared to the mean of reference stations for the clam *M. nasuta,* also used in the bioaccumulation tests, and the difference in percent survival was greatest for BA-4. However, this apparent effect was not tested statistically.

Factor 9 Magnitude by which contaminants whose bioaccumulation from the dredged material exceeds that from the reference material also exceeds the concentrations found in comparable species living in the vicinity of the proposed disposal site.

This factor is to be used only if agreement between the EPA and USACE cannot be reached based on the first eight factors and a field study must be designed and executed

3.6.2 Interpretations

A field study under Factor 9 is not necessary, since *N virens* exhibited no bioaccumulation above background tissue levels and barium was the only metal accumulated in *M nasuta* tissues. Significant ecological impacts would not be expected from the bioaccumulation exhibited by these bioaccumulation studies based on the first eight factors. Further discussion of this factor is beyond the scope of this report

The metals concentrations in the *M nasuta* tissues exposed to test sediments were not significantly higher than the respective concentrations in reference control organisms, with the exception of BA-1 for barium (Tables 10 and 11, Appendix B, Tables B-10 through B-13). The metals concentrations in the *N virens* tissues exposed to test sediments were not significantly higher than reference control tissues and background tissue levels These indicate a lack of bioaccumulation of chromium and barium in *N. virens* exposed to test sediment Bioaccumulation was only shown for barium in one species, but barium has no FDA action level because its physical and chemical properties generally preclude the existence of the toxic soluble form under usual marine conditions (EPA, 1986). The FDA does not have a Guidance Document for barium

4. SUMMARY

Chemical analyses were conducted on water, elutriate, and sediment samples from 26 stations in the GIWW through the Laguna Madre and on samples from reference stations. Solid phase bioassays and bioaccumulation studies were also conducted on sediment from six test stations, on reference control sediment, on a true control (clean beach sand), and on background levels in test organism samples For each sampling station, Table 15 lists the number of detected metals (10 maximum) in the sediments and the number for which a sediment quality guideline was exceeded The water and elutriates are summarized according to the number of analytes above the EPA WQC. The bioassay toxicity results are summarized based on the occurrences of survival differences greater than 10% (20% for amphipods) when compared to the reference sediment results Similarly, the tissue work is summarized according to the number of analytes detected and the number that were significantly higher than the reference control.

The combined sediment, water and elutriate results show the greatest number of exceedances of criteria or guidelines near LM-8, near the mouth of Baffin Bay (ULM) and near LM-16 near mouth of the North Floodway (LLM) The water and elutriate samples showed detectable levels of TPH, arsenic, barium, cadmium, chromium, copper, lead, and zinc at more than one station (e.g., TPH was found in 5 water and 5 elutriate samples). Highest concentrations of TPH occurred in water at LM-7, near Baffin Bay (5,400 μg/L) and in elutriate at LM-15, near the North Floodway (1,160 μg/L)

- Arsenic was detected in all but two water samples and in all elutriates. The highest elutriate values of 17.9 to 18.5 mg/l occurred in the ULM at LM-6, 7, and 9 with the concentrations well below the marine acute (69 μg/L) and marine chronic (36 μg/L) WQC.

- Barium was detected in all water and elutriate samples. There are no federal or state standards for barium, but the Gold Book Criterion (EPA, 1986) is 1,000 μg/L barium for domestic water supply The only value to exceed 1,000 μg/L barium was the LM-5 elutriate value of 1,320 μg/L.

- Cadmium was also detected at most stations, with the highest values occurring in water samples from BA-1, LM-12, and LM-14; and in elutriate samples from LM-5, LM-12, and BA-4. The marine acute and marine chronic WQC for cadmium were not exceeded at any station

- Chromium concentrations in both water and elutriates included large station-to-station variability with no apparent trends Highest water concentration was found at LM-2 (27.8 μg/L), while the highest elutriate concentrations were found at LM-4 (10 7 μg/L) and LM-11 (10.6 μg/L)

Chromium concentrations in elutriates were numerically higher than those in the water for most stations Although there are no EPA marine WQC for total chromium, the TWQS for hexavalent chromium of 1,100 µg/L acute and 50 µg/L chronic were not exceeded.

- Copper criteria were exceeded at all 28 water sample stations and in all but one elutriate sample, with station LM-2 the exception Copper is discussed further below

- Lead was detected in all but 8 water and all but 9 elutriate samples. The highest concentrations exceeded the EPA marine chronic WQC of 5.6 µg/L and were found in water at LM-2 (7 49 µg/L) and LM-11 (6 80 µg/L), and in elutriate at LM-2 (22 60 µg/L) and BA-4 (7.5 µg/L) No samples exceeded the EPA marine acute WQC of 140 µg/L The ratio of lead concentrations in elutriates versus water varied and no trends were evident

- Zinc was detected in all water samples and all but one elutriate sample (LM-17). The EPA marine acute (95 µg/L) and chronic (86 µg/L) criteria for zinc were exceeded only in the water samples near the mouth of Baffin Bay at LM-6, BA-3, LM-8, and LM-9, and also in the lower lagoon near the mouth of North Floodway at LM-16 Zinc concentrations ranged from 133 to 415 µg/L at these stations

The following summarizes the results and interpretations of all aspects of the sampling, including the above water and elutriate results.

Sediment composition. The sediment composition (Table 3-1) is primarily silt and fine sand size particles, with mean particle size averaging 0.08 mm and ranging from 0.01 to 0.21 mm. The finer materials occur between LM-5 and LM-9 in the lower half of the Upper Laguna Madre, and between LM-11 and LM-15 in the upper half of the Lower Laguna Madre.

TPH, TOC, phenols, PCBs and pesticides The TPH, phenols, PCBs, and pesticides analyses were below detection limits in all sediment samples TOC was analyzed by method 413 2, an oil and grease determination with an MDL of 5 0 mg/kg Espey, Huston and Associates (EHA, 1998) reported one TOC sample, LM-1 (Corpus Christi Bay) with detectable levels, at 7 2 mg/kg In general, the highest concentrations of most metals in sediment occurred at stations with a predominantly silt/clay (i e , fine-grained) sediment type, especially at the mouth of Baffin Bay south toward the Land Cut (LM-6 through LM-9) (Table 3-2). Effects Range Low (ERL) and Effects Range Medium (ERM) sediment guidelines developed by Long et al (1995) were used for comparison to these results. LM-6 had the highest sediment concentration of five of the ten metals (chromium, copper, lead, nickel and zinc), though none exceeded ERLs LM-8 had the highest sediment concentration of barium, cadmium and mercury. The concentrations of arsenic in sediments at stations LM-11 and BA-6 and of cadmium at stations LM-8 and BA-4 substantially exceeded both respective ERLs and ERMs. Thus, these parameters could represent cause for concern in sediment from those locations. The sediment concentrations of mercury slightly exceeded only the ERL at stations LM-8 and LM-12. As with the metals results, the stations located in the vicinity of Baffin Bay toward the Land Cut had the highest total sulfide and ammonia sediment concentrations, associated with finer grain sizes.

Water and elutriate. For water and elutriate, lead, zinc and copper exceeded EPA Marine Water Quality Criteria. Zinc exceeded acute criteria in the water column at five stations· LM-6, BA-3, LM-8, LM-9 and LM-16 As with sediment, most of these stations are in the vicinity of Baffin Bay and south toward the Land Cut. One (LM-16) is in the Lower Laguna Madre between the North Floodway Outlet Channel and Arroyo Colorado. Lead exceeded chronic criteria in both the water and elutriate samples at LM-2, and exceeded chronic criteria at LM-4 (elutriate) and LM-11 (water). Note that all metals measured in water samples are total, not dissolved, concentrations, while metals measured in elutriate samples are dissolved concentrations because of the elutriate preparation methodology (EHA, 1998). Therefore, minor apparent exceedances of criteria in water samples may not be exceedances in fact, as the criteria are for dissolved concentrations.

All stations, including reference sites, exceeded EPA's marine criteria for copper in both water and elutriate (except LM-2 elutriate) EPA's marine criteria for copper, unlike other metals, are significantly more stringent than the Texas marine criteria: acute = 2 9 vs. 16.27 ug/l; chronic = 2 9 vs. 4 37 ug/l, respectively. Using the Texas standards, most stations would still exceed the chronic criterion, but not the acute criterion.

The high levels of copper raise the possibility that the water column in the channel may have exceeded the assimilative capacity for copper However, research related to copper suggests that, because of sampling and analytical difficulties, apparent high levels of copper are not certain indicators of a water quality problem in Laguna Madre Rather, they indicate a need for further investigation, and a need for ultraclean sampling using the latest methods from USGS for the most accurate estimates of dissolved (rather than total) concentrations For additional discussion of this subject, refer to the companion report to this one, entitled Alternatives for Beneficial Use of Dredged Material, Laguna Madre, Texas, Section 3 4 1, "Characteristics of Dredged Material"

Ultraclean sampling The ultraclean results suggested that most of the routine sampling was reliable Only potential contamination of TPH was indicated. Future analysis of copper samples should include the latest USGS methods for dissolved results.

Bioassay toxicity testing The solid phase toxicity bioassay results indicated that, except for sampling station BA-4 (North Floodway Outlet Channel), there appears to be no potential for environmentally unacceptable lethal impacts on benthic organisms from the disposal of any ULM or LLM sediments. Survival of organisms exposed to test sediments in the solid phase bioassays was not significantly different from survival of organisms exposed to the solid phase of the reference control. The exception was sampling station BA-4 for one of the two test species, where there was a significant (though marginal) difference between mean survival rates of *Ampelisca abdita* in material from BA-4 and from reference stations This may indicate a potential to impact benthic organism survival due to placement of materials from the vicinity of sampling site BA-4, suggesting that material removed from that reach may not be suitable for disposal at the offshore sites However, the results for BA-4 are only marginally significant, and it would be prudent to consider further testing of sediments from this area before final disposition of any dredged material from this area is determined Espey, Huston and Associates (EHA, 1998) point out that the difference in survival between sampling station BA-4 and the reference controls was 20.5%, only marginally above the cutoff value of 20%. Also, survival of *A abdita* was low in sediments from REF2 (Brazos Island Harbor ODMDS) and all of the Lower Laguna Madre stations, and the difference between the tabulated and calculated t-values was small

Tissue bioaccumulation testing. Uptake of barium at BA-1 was shown in *M nasuta* relative to reference control tissues. The concentrations of barium (BA-1, BA-5, and BA-6) and chromium (BA-5) in tissues of *N virens* were significantly higher than in the reference control and true control, but not compared to background tissue concentrations. Significant ecological impacts would not be expected from the bioaccumulation exhibited by these bioaccumulation studies.

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6. FIGURES

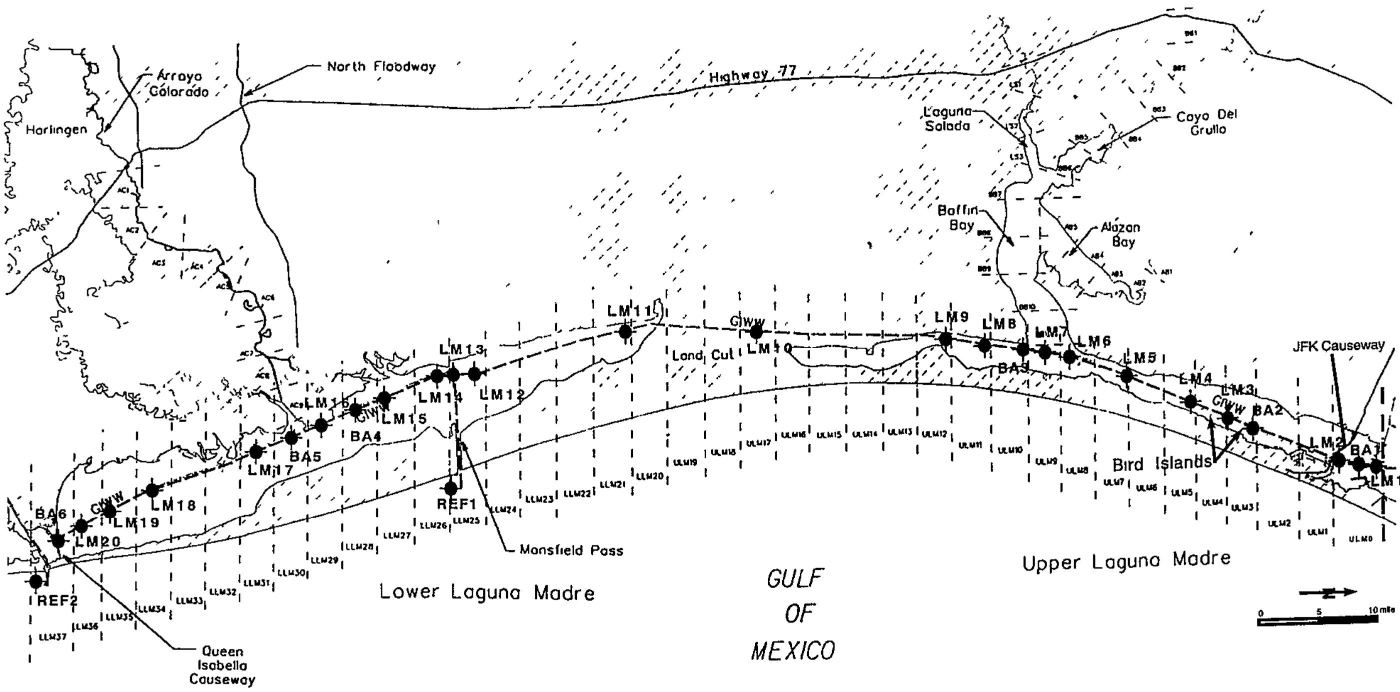

Figure 1. Location of sampling sites

Collecting sediment samples with the box corer.

Collecting water samples via a peristaltic pump and filling of sample containers.

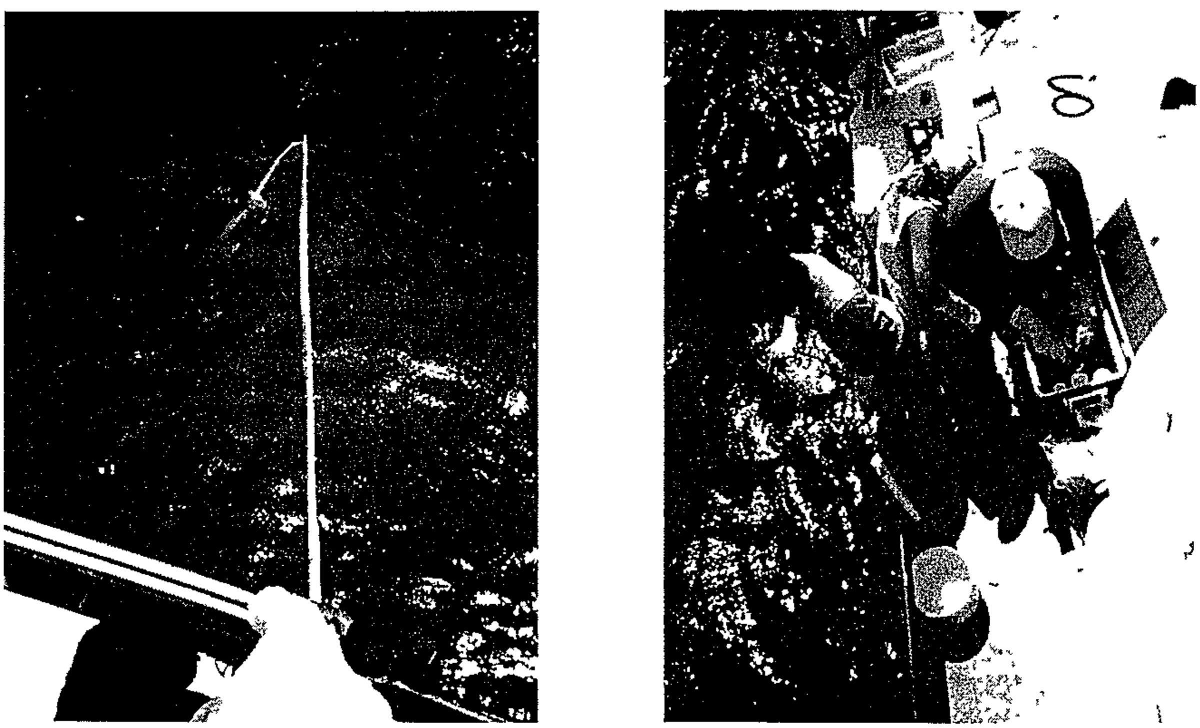

Figure 2: Sediment and Water Sampling, Laguna Madre, Texas (June 1997)

Coastal Environments, Inc
Baton Rouge, Louisiana

7. TABLES

Table 1 Locations of sampling sites

Sampling Station	Location	Latitude	Longitude	Distance along GIWW in feet	Segment Number	Maintenance Need	Sample Type
Corpus Christi Bay > Land Cut							
LM1		27 40 06	97 13 82	10+000	ULM0	H	W/S
BA1	C Christi Bay	27 39 54	97 14 05	15+000	ULM0	H	W/S/BA
LM2	JFK Causeway	27 38 31	97 14 52	25+000	ULM0	H	W/S
BA2	North Bird Island	27 33 45	97 16 86	65+000	ULM3	L	W/S/BA
LM3		27 31 99	97 17 60	75+000	ULM4/5	L	W/S
LM4		27 28 37	97 19 45	95+000	ULM5	M	W/S
LM5		27 24 85	97 21 49	125+000	ULM6/7	M	W/S
LM6	Baffin Bay	27 18 45	97 24 22	155+000	ULM8	M	W/S
LM7	Baffin Bay	27 17 12	97 24 52	165+000	ULM9	H	W/S
BA3	Baffin Bay	27 15 54	97 24 88	175+000	ULM10	H	W/S/BA
LM8		27 12 26	97 25 48	190+000	ULM11	H	W/S
LM9		27 09 46	97 26 10	210+000	ULM12	H	W/S
LM10	Land Cut	26 55 18	97 27 46	295+000	ULM17	L	W/S
Land Cut >Port Isabel							
LM11		26 45 39	97 27 57	285+000	LLM20/21	H	W/S
LM12		26 35 42	97 24 41	215+000	LLM25	M	W/S
LM13	Port Mansfield	26 33 09	97 24 25	205+000	LLM25/26	H	W/S
LM14		26 32 61	97 24 24	200+000	LLM26	H	W/S
LM15		26 28 43	97 22 47	175+000	LLM27	M	W/S
BA4	North Floodway	26 26 01	97 21 38	160+000	LLM28/29	L	W/S/BA
LM16		26 23 31	97 20 16	145+000	LLM29	L	W/S
BA5	Arroyo Colorado	26 21 44	97 19 30	130+000	LLM30	H	W/S/BA/UC
LM17		26 18 71	97 18 03	115+000	LLM31	L	W/S
LM18	Cheryl Shoal	26 11 22	97 15 20	65+000	LLM34	H	W/S
LM19	Cheryl Shoal	26 09 34	97 14 17	45+000	LLM35	H	W/S
LM20		26 07 53	97 13 13	30+000	LLM36	L	W/S
BA6	Q Isabella Causeway	26 04 44	97 11 86	15+000	LLM37	M	W/S/BA/UC
Gulf of Mexico							
REF1	Port Mansfield Channel	26 32 05	97 14 11		ODMDS		W/S/BA
REF2	Brazos Santiago Channel	26 02 11	97 07 12		ODMDS		W/S/BA
CCREF	Corpus Christi Channel	27 50 45	96 59 59		ODMDS		BA

Sample type W=water, S=sediment, BA=Bioassay, UC=Ultraclean
Maintenance need H=high, M=Medium, L=low

Table 2 Description of and rationale for sample sites.

REF1	Port Mansfield ODMDS	EPA specified.
REF2	Brazos Island harbor ODMDS	EPA specified.
CCREF	Corpus Christi ODMDS	EPA specified
BA1	Corpus Christi Bay	EPA specified near Corpus Christi Bay, center of frequently dredged reach GIWW from Corpus Christi Bay to JFK Causeway.
LM1 and LM2		Bracket BA1 and frequently dredged reach from Corpus Christi Bay to JFK Causeway.
BA2 and LM3		EPA specified near Bird Island; sample sites occupy the two most frequently dredged sections of this low-maintenance segment of the GIWW. BA2 is located near mineral industry activities in the vicinity of North Bird Island
LM4 to LM6 (LM5 in center)		Bracket GIWW reach subject to medium-frequency dredging
LM6 to LM9 (LM6 contingent)		GIWW segment requiring frequent maintenance dredging, adjacent and south of Baffin Bay
BA3	Baffin Bay	EPA specified near Baffin Bay, occupies section with greatest dredging frequency and volume.
LM10		In center of Land Cut area for informational purpose; very little data available for this area because of very limited dredging need between LM9 and LM11.
LM11		Localized, high dredging-frequency because of southward GIWW flow becoming unconfined.
LM12 to LM14		Bracket frequently dredged section at GIWW-Port Mansfield Channel intersection. LM14 is located at intersection, LM13 and LM 15 are each located at GIWW bend where shoaling is greatest.
LM15		Center of segment with medium maintenance frequency extending northward from North Floodway outlet.
BA4	North Floodway outlet channel	EPA specified at North Floodway
LM16		Contingent - intermediate between North Floodway outlet channel and Arroyo Colorado in the event one of two sites gives reason for concern.
BA5	Arroyo Colorado	EPA specified Arroyo Colorado
LM17		Southern limit of maintenance dredging in Arroyo Colorado area.
LM18 to LM19		Bracket area of shoaling in Lower Laguna Madre due to general circulation (Cheryl Shoal).
LM20		Intermediate between area of concern at Port Isabel and Cheryl Shoal
BA6	Port Isabel	EPA specified near Port Isabel, located in most frequently dredged portion of GIWW near Brazos Santiago Channel.

Table 3 Analytical methods and minimum detection limits

Parameter	Detection Limit	EPA Method	Detection Limit	EPA Method
	Sediment		**Water/Elutriate**	
METALS				
Arsenic	100 µg/kg	7060	1 0 µg/L	206.2
Barium	100 µg/kg	7080	1.0 µg/L	210 2
Cadmium	100 µg/kg	7131	0 1 µg/L	213.2
Chromium	100 µg/kg	7191	1 0 µg/L	218.2
Copper	100 µg/kg	7211	1.0 µg/L	220 2
Lead	100 µg/kg	7421	1.0 µg/L	239 2
Mercury	200 µg/kg	7471	0 2 µg/L	245.1
Nickel	100 µg/kg	7521	1.0 µg/L	249 2
Selenium	200 µg/kg	7740	2.0 µg/L	270 2
Silver	100-µg/kg	7761	1 0 µg/L	272.2
Zinc	100 µg/kg	7951	1.0 µg/L	289 2
PESTICIDES				
Aldrin	10 µg/kg	8080	0 04 µg/L	608
Alpha-BHC	10 µg/kg	8080	0 02 µg/L	608
Beta-BHC	10 µg/kg	8080	0.02 µg/L	608
Gamma-BHC	10 µg/kg	8080	0.02 µg/L	608
Delta-BHC	10 µg/kg	8080	0 02 µg/L	608
Chlordane	10 µg/kg	8080	0.14 µg/L	608
p,p'-DDD	10 µg/kg	8080	0 12 µg/L	608
p,p'-DDE	10 µg/kg	8080	0 12 µg/L	608
p,p'-DDT	10 µg/kg	8080	0.12 µg/L	608
Dieldrin	10 µg/kg	8080	0.02 µg/L	608
Endosulfan I	20 µg/kg	8080	0.14 µg/L	608
Endosulfan II	20 µg/kg	8080	0.14 µg/L	608
Endosulfan Sulfate	20 µg/kg	8080	0 14 µg/L	608
Endrin	10 µg/kg	8080	0 06 µg/L	608
Endrin Aldehyde	10 µg/kg	8080	0 06 µg/L	608
Heptachlor	20 µg/kg	8080	0 03 µg/L	608
Heptachlor Epoxide	20 µg/kg	8080	0 03 µg/L	608
Toxaphene	50 µg/kg	8080	0 50 µg/L	608

Table 3 (continued)

Parameter	Detection Limit	EPA Method	Detection Limit	EPA Method
	Sediment		**Water/Elutriate**	
PAHs				
Acenaphthene	30 µg/kg	8270	2 00 µg/L	625
Acenaphthalene	30 µg/kg	8270	2.00 µg/L	625
Anthracene	30 µg/kg	8270	0 50 µg/L	625
Benzo(a)anthracene	30 µg/kg	8270	1 00 µg/L	625
Benzo(b)fluoranthene	30 µg/kg	8270	0.10 µg/L	625
Benzo(k)fluoranthene	30 µg/kg	8270	0 10 µg/L	625
Benzo(ghi)perylene	30 µg/kg	8270	0 10 µg/L	625
Benzo(a)pyrene	30 µg/kg	8270	0 50 µg/L	625
Benzo(e)pyrene	30 µg/kg	8270	0 50 µg/L	625
Chrysene	30 µg/kg	8270	0 50 µg/L	625
Dibenzo(ah)anthracene	30 µg/kg	8270	0 50 µg/L	625
Fluoranthene	30 µg/kg	8270	0 50 µg/L	625
Fluorene	30 µg/kg	8270	0.50 µg/L	625
Indeno(1 23-cd)pyrene	30 µg/kg	8270	0 50 µg/L	625
Naphthalene	30 µg/kg	8270	2.00 µg/L	625
Phenanthrene	30 µg/kg	8270	1.00 µg/L	625
Pyrene	30 µg/kg	8270	0 50 µg/L	625
Total	500 µg/kg	8270	5 00 µg/L	625
PCBs				
Total	5 µg/kg	8080	0 50 µg/L	608
MISCELLANEOUS				
Ammonia-N	0 1 mg/kg	Plumb, 1981	N/A	
Phenols	10 mg/kg	8040	50 µg/L	420 1
Total organic carbon	5 0 mg/kg	413 2	5 0 mg/kg	413.2
Total Petroleum Hydrocarbons	100 mg/kg	418 1	100 µg/L	418 1
Total Solids	0.01%	Plumb, 1981		N/A
Total Sulfide	0.1 mg/kg	Plumb, 1981	N/A	
Total Volatile Solids	0 1 mg/kg	Plumb, 1981	N/A	
Total Lipids (tissue analysis only)	0.1%	Lee et al ,1989		

All methods unless noted are found in U S EPA, "Test Methods for the Evaluation of Solid Waste," SW-846, November 1990

Table 4 Physical parameters of water (June 1997), Laguna Madre, Texas

Site	Date	Water Depth (ft)	Sample Depth (ft)	DO (mg/l)	pH	Salinity ($^{0}/_{00}$)	Water Temp (°C)	Secchi Depth (ft)
Ref1	6/7/97	45 0	3*	6 75	8 12	32 7	24 0	4 5
			10	6 70	8 14	32 7	23 6	
			20	6 11	8 10		22 7	
			30	6 09	8.12		22.7	
			45**	4.70	8 07		21.7	
Ref 2	6/8/97	47 0	3*	6 73	8 20	33 3	25 1	6 2
			10	6 58	8 20	33 2	25.1	
			20	6 58	8 20	33 3	24 7	
			47**	5 78	8 18	-	24.3	-
LM1	6/5/97	11 0	3*	7 64	8 41	28.1	28.0	4 0
			10**	6.55	8.47	31 0	28 0	
LM2	6/5/97	14.0	3*	5 85	8 67	38.0	28.2	3 0
			16**	5 26	8 65	38 2	28 1	
LM3	6/5/97	13.5	3*	5 58	8.52	40 1	28 0	2.5
			12**	5.15	8 52	40.1	28.0	
LM4	6/5/97	14 0	3*	6 06	8 56	39 0	27 8	2 5
			12**	5 50	8.58	39 1	27 9	
LM5	6/9/97	16 0	3*	6 03	8 61	35 4	29 8	2 5
			14**	2 75	8.55	35 7	29.0	
LM6	6/9/97	17.0	3*	5.27	8 50	33.2	29 1	2 5
			15**	4 18	8 51	36 1	29 1	
LM7	6/9/97	16 0	3*	5.02	8 46	32 9	29.1	2 0
			14**		8 39	33.7	28 8	
LM8	6/9/97	19.0	3*	5 86	8 62	28 7	28 8	2 2
			17**	3 44	8 02	28 5	28.8	
LM9	6/9/97	15 0	3*	5 64	8 64	25 6	28 4	3 0
			10	4 06	8 69	26 1	28 5	
			13**	4 18	8 68	30.5	28 4	
LM10	6/6/97	20 1	3*	5 85	8 52	27 5	29 0	2 5
			15**	5.66	8 57	27 2	28.9	
LM11	6/6/97	13 0	3*	6 45	8 49	25 7	29 0	3 0
			13**	6 34	8 47	26 1	28 5	
LM12	6/6/97	12 5	3*	6 73	8 47	24 2	28 9	2 3

*Approximate water sample depth below surface
**Approximate sediment sample depth below water surface

Table 4 (continued)

Site	Date	Water Depth (ft)	Sample Depth (ft)	DO (mg/l)	pH	Salinity (‰)	Water Temp (°C)	Secchi Depth (ft)
			10**	6.36	8.45	24.2	29.0	
LM13	6/6/97	16.5	3*	6.18	8.60	25.7	29.2	3.0
			8	5.79	8.60	27.2	29.1	1.8
			14**	4.57	8.55	29.7	28.2	
LM14	6/6/97	10.3	3*	6.04	8.59	25.2	29.2	2.0
			10**	6.09	8.59	25.5	29.0	
LM15	6/8/97	14.0	3*	6.12	8.91	29.0	29.0	2.0
			12**	6.09	8.91	29.0	29.0	
LM16	6/8/97	19.5	3*	7.04	8.79	23.5	29.3	3.0
			17**	4.90	8.80	28.2	28.0	
LM17	6/8/97	20.0	3*	5.20	8.94	30.8	27.9	2.0
			14**	4.80	8.93	31.1	27.7	
LM18	6/8/97	13.0	3*	5.55	8.32	30.5	28.4	4.0
			11**	5.26	8.31	30.7	28.3	
LM19	6/8/97	11.0	3*	5.56	8.45	31.4	27.8	5.0
			11**	5.26	8.45	31.3	27.7	
LM20	6/8/97	16.0	3*	5.97	8.32	33.0	25.9	5.0
			14**	5.96	8.32	32.9	28.9	
BA1	6/5/97	14.0	3*	7.06	8.52	29.3	27.9	5.0
			12**	5.75	8.67	37.6	28.2	
BA2	6/5/97	10.3	3*	5.15	8.54	40.0	27.9	2.4
			10**	4.91	8.54	40.1	27.9	
BA3	6/9/97	18.6	3*	5.49	8.61	31.8	29.1	2.8
			16**	4.23	8.58	33.0	29.1	
BA4	6/8/97	19.7	3*	6.33	8.88	28.2	28.7	1.8
			14**	6.34	8.87	28.7	28.1	
BA5	6/8/97	19.0	3*	5.61	8.93	30.9	27.8	3.5
			17**	5.64	8.93	31.2	27.7	
BA6	6/7/97	20.0	3*	5.96	8.20	32.1	26.0	4.0
			10	5.28	8.13	32.3	23.3	
			20**	5.40	8.13	33.6	23.2	

*Approximate water sample depth below surface
**Approximate sediment sample depth below water surface

Table 5 Summary grain size results (June 1997), Laguna Madre, Texas

Sample	Mean Size (mm)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Sediment (%)
LM1	0 16	1 9	79 3	17 7	1 1	100
BA1	0 19		83 7	8 9	7 4	100
LM2	0 15	10 2	51.2	30 4	8 2	100
BA2	0 10		52 6	40 3	7.1	100
LM3	0.15		79 9	18 4	1 7	100
LM4	0 15		65 1	28 7	6 2	100
LM5	0 01		4.9	85 5	9 6	100
LM6	0 01		4 9	85 5	9 6	100
LM7	0 01		9.7	74 9	15 4	100
BA3	0 05		2 6	85.0	12 4	100
LM8	0 01		15 3	68 0	16 7	100
LM9	0.01		11 2	83 8	5 0	100
LM10	0 20	0 2	75 3	19 5	5 0	100
LM11	0 01		14.6	79 6	5 8	100
LM12	0.01	2 5	18.1	68 2	11.2	100
LM13	0 01	0 5	7.9	70 3	21 3	100
LM14	0 02		34 6	57.8	7 6	100
LM15	0 06		32 2	64 1	3 7	100
BA4	0 11		56 0	42 2	1 8	100
LM16	0.16		54 6	45 4		100
BA5	0 06		36 6	60 8	2 6	100
LM17	0 06		34 8	61.5	3 7	100
LM18	0.01		18 0	73 4	8 6	100
LM19	0 02		26.8	65.0	8 2	100
LM20	0.17		65 8	34 2		100
BA6	0 08	0 6	52 3	39 8	7 3	100
Ref 1	0 21	2 1	96 0	1 7	0 2	100
Ref 2	0 12		67 4	20 8	11 8	100
CCREF	0 18		82.9	11 4	5 7	100
Average	0 08	2 6	41 1	51 1	7 7	
Maximum	0 21	10 2	96 0	85 5	21 3	
Minimum	0 01	0 2	2 6	1 7	0 2	

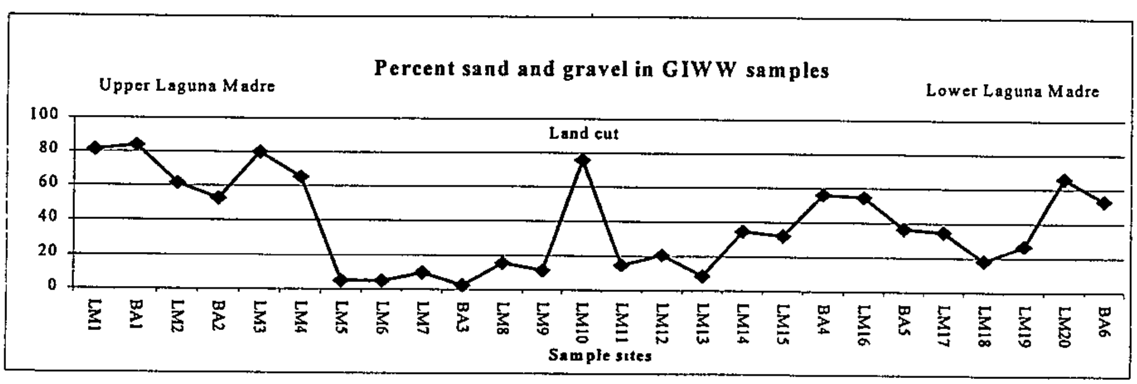

Table 6 Analytical results for sediments (mg/kg), June 1997, Laguna Madre, Texas

Parameter[1]	ERL[2]	ERM[3]	LM-1	BA-1	LM-2	BA-2	LM-3	LM-4	LM-5	LM-6	LM-7	BA-3	LM-8	LM-9	LM-10	REF-1	CCREF*
Arsenic	8.2	70	0 6	2.2	1.7	5 0	1.8	2.1	4.6	3 6	2.3	4.5	2 2	2 3	0.21	4.75	<1.0
Barium			63.9	69 0	225.0	215.0	114.0	260.0	266.0	39 9	274 0	205.0	188 0	136.0	38.30	10.10	
Cadmium	1 2	9 6	<0.1	0.1	0.3	0.6	0.4	0.3	0.3	<0.1	<0 1	<0.1	**40.1**	<0 1	0.32	<0.10	<0 1
Chromium	81		0 6	3.7	12.4	17.5	6.3	11.6	20 3	26.8	26 2	15.1	17 6	15.3	7.14	4.36	4 50
Copper	34		1 8	2 9	9.7	9.8	5.2	9.6	10 5	18.8	16.5	11 9	13 3	13.8	5 60	1.49	20.00**
Lead	46.7		1 5	2.2	4.3	4.5	2.4	4 1	8.4	15.1	13.3	11.6	12.7	3.3	3.04	1.95	<1 0
Mercury	0.1	0.71	<0 0	<0 0	<0.0	<0.0	<0.0	<0.0	<0 0	<0.0	<0 0	0.1	0 2	<0.0	0.05	<0 02	<0.1
Nickel	20 9		2 7	2 2	8.2	9.2	4.2	5.8	12.0	17.0	17.0	12.3	13.7	12 2	5.53	1.27	4 20
Selenium			0 2	0 2	0 2	0 2	<0.2	<0 2	0.4	0.3	0.2	0 2	1 0	0.2	0 20	<0.20	<0.5
Zinc	150		14.9	25.0	51 7	55.4	41.6	36.9	59 3	74.5	73.5	49.8	56 3	55 0	22.90	14.00	17.9
Total sulfide			66 3	97.4	488.0	64.3	76.3	383.0	129.0	219.0	304 0	213 0	193.0	252 0	147.0	<0.10	
Ammonia-N			2 3	3.7	56.8	82.6	4.5	31.4	52.1	273 0	240 0	208.0	217.0	378 0	31.50	2.26	
% Total solids			75 1	67.3	44.0	42.7	59.8	45.5	37.1	22.2	19 8	25 8	28.6	21 2	53.70	82.25	
% Volatile solids			1 3	2 2	3 5	3 3	2.6	3 9	4 4	3.7	4.1	4.0	4 0	4.4	3 60	1.11	
% Sand			79 3	83.7	51.2	52.6	79.9	65.1	60.4	4.9	9 7	2 6	15.3	11 2	75 3	98 1	82 9
% Silt			17 7	8 9	30 4	40 3	18.4	28.7	10.9	85.5	74.9	85 0	68.0	83 8	19.5	1.7	11.4
%Clay			1.1	7.4	8 2	7.1	1.7	6.2	28.7	9.6	15.4	12.4	16.7	5 0	5.0	0.2	5.7

Bold type = exceeded criterion

*Values are highest of six samples dated 04-Apr-90.

**The other 5 copper samples were <1.0

Additional footnotes on next page.

Table 6 (continued)

Parameter[1]	ERL[2]	ERM[3]	LM-11	LM-12	LM-13	LM-14	LM-15	BA-4	LM-16	BA-5	LM-17	LM-18	LM-19	LM-20	BA-6	REF-2
Arsenic	8.2	70	**583.00**	4.64	5.56	**11.40**	2.31	4.67	1.51	2.60	2 50	2 73	5.11	3.99	**383.00**	4.65
Barium			58.00	91.00	94.80	80.40	54.70	114.00	73.10	125.00	121 00	164 00	97.40	174 00	22.10	57 20
Cadmium	1 2	9.6	<0 10	<0.10	0.31	<0.10	<0.10	10.00	0.18	<0.10	<0.10	<0 10	<0.10	<0.10	0.17	<0 10
Chromium	81		18.20	15.90	16.40	13.40	9 13	24.30	9 94	18.20	16 60	18 70	16.20	11 00	3.01	7 65
Copper	34		12.00	9 02	11.80	9.11	4 23	13.10	5.30	9.94	10.30	10 20	8 58	3.67	1 57	5 62
Lead	46.7		5.42	4 86	5.28	4.31	3.84	7.54	3.78	6 41	6.79	7 79	7 39	5.18	3 01	5.12
Mercury	0 15	0.71	<0 02	**0.17**	0.07	<0.02	<0.02	<0.02	<0 02	<0.02	<0 02	<0 02	<0.20	<0.02	0.08	0 07
Nickel	20.9		13.30	12 90	13.90	11.80	5.31	14.10	6 51	11 20	10 10	12 80	11 10	7.24	0 79	6.67
Selenium			0 20	0.20	<0 20	<0 20	<0.20	0 96	<0.20	<0 20	<0 20	<0.20	<0 20	<0 20	0 20	<0 20
Zinc	150		56.10	51 80	62.50	48.20	23 90	25.90	27 90	49.00	46 10	52 90	49.10	33 00	9.07	30 30
Total Sulfide			447.00	73.40	51.90	97.00	90.80	89.10	106 00	198.00	71 50	206 00	194.00	44 90	14.00	12 10
Ammonia-N			233.00	33 50	63.60	23.90	10.40	31.10	9 50	25.80	9.13	65.00	65 60	2.20	2 46	12 60
% Total Solids			31 30	36 50	38.63	43.31	78 90	50.40	56.28	53 60	53.90	42 70	44 56	56 30	74 81	77 20
% Volatile Solids			4.50	4 76	5.00	4 69	2.94	4 48	4.24	5 08	5 32	5 31	5 31	4 24	2 69	4.34
% Sand			14 6	20.6	8.4	34 6	32.2	56 0	54 6	36 6	34 8	18 0	26 8	65.8	52 9	67 4
% Silt			79 6	68 2	70 3	57 8	64.1	42.2	45.6	60 8	61.5	73 4	65.0	34 2	39.8	20 8
% Clay			5 8	11.2	21.3	7 6	3.7	1 8	0.0	2 6	3.7	8 6	8 2	0 0	7 3	11 8

1 Results for TOC, TPH, PCBs, phenols, and pesticides were all below detection limits
2 ERL = Effects range low (Long et al , 1995)
3 ERM = Effects range medium (Long et al., 1995), listed only if ERLs are exceeded.
Bold type = exceeded criterion

Table 7: Analytical results for water (µg/L), June 1997, Laguna Madre, Texas

	EPA Marine WQC																
Parameter	**Acute**	**Chronic**	**LM-1**	**BA-1**	**LM-2**	**BA-2**	**LM-3**	**LM-4**	**LM-5**	**LM-6**	**LM-7**	**BA-3**	**LM-8**	**LM-9**	**LM-10**	**REF-1**	**CCREF**
Arsenic	69	36	1.80	1.20	1 10	1.10	1.20	<1.00	1.40	1.50	1.70	1 70	1 30	1.60	1 50	<1.00	<2.0
Barium	na	na	53.20	54 30	75.80	67.10	59 00	63 20	63.40	63.20	61.30	57.50	54.60	48.00	49.40	16.70	
Cadmium	43	9.3	1.50	2.20	0.70	0.70	0.90	1.90	0.20	0 30	<0 10	0.20	0.30	0.30	0 70	1.10	<2.0
Chromium	1100*	50*	4.50	6.60	27 80	3 80	3.30	5.60	2.30	2 60	1.30	2.80	2 90	3.80	3 90	4.30	<10 0
Copper	2 9	2 9	**9.80**	**11.80**	**33.30**	**7.60**	**18.90**	**10.80**	**7.70**	**7.90**	**4.90**	**7.80**	**7.80**	**15.70**	**9.20**	**8.70**	<1 0
Lead	140	5 6	1 90	1 70	**7.49**	<1.00	<1 00	1 44	1.40	2.50	<1 00	1.30	<1.00	2 10	2.50	1.20	<5.0
Zinc	95	86	34 40	47.40	51.20	20 40	29.40	46.90	78.60	**133.00**	10 10	**201.00**	**129.00**	**415.00**	42.10	26.50	<5.0
TPH	na	na	<100	<100	<100	<100	<100	<100	<100	<100	5,400	<100	<100	<100	<100	<100	

	EPA Marine WQC															
Parameter	**Acute**	**Chronic**	**LM-11**	**LM-12**	**LM-13**	**LM-14**	**LM-15**	**BA-4**	**LM-16**	**BA-5 / UC**	**LM-17**	**LM-18**	**LM-19**	**LM-20**	**BA-6 / UC**	**REF-2**
Arsenic	69	36	1.60	1 90	1.60	1 90	1.80	2.10	2 20	2.10 1 50	1.40	1 50	1.40	1.40	1.40 1 50	1 20
Barium	na	na	40 00	52 20	42.00	50.50	51.90	49.40	56.00	48 80 44 70	42.60	34.90	22 20	15 90	17.70 16.80	12.10
Cadmium	43	9.3	0.80	2 00	0.60	3 60	<0.10	0.20	0.20	0 30 0.40	0.30	0.30	0.40	<0 10	1 80 0 30	1.70
Chromium	1100*	50*	6.70	5.90	3 70	<1.00	1 50	3 11	2.20	2.30 3 40	3 60	3 50	4.30	1.50	9.40 3.10	6 40
Copper	2 9	2 9	**10.20**	**12.40**	**10.50**	**9.70**	**7.70**	**5.60**	**7.50**	**7.80 7.10**	**8.80**	**10.80**	**11.30**	**6.50**	**7.90 5.80**	**10.00**
Lead	140	5 6	**6.80**	1.90	3 10	2.90	<1.00	<1.00	<1.00	1.10 <1.00	1.90	1 40	1 20	<1 00	1.20 1.50	2 60
Zinc	95	86	63 50	38.70	39.80	33.10	24 80	27 70	**158.00**	38.90 23.70	29.50	33.00	36 70	28.60	31.50 28.20	25.30
TPH	na	na	<100	<100	<100	<100	130	<100	130	200 <100	<100	<100	<100	410	<100 <100	<100

* These are criteria for hexavalent chromium
na = no criteria available
UC = Ultraclean
Bold type = exceeded criterion

Table 8 Analytical results for elutriates (µg/L), June 1997, Laguna Madre, Texas

	EPA Marine WQC																
Parameter	**Acute**	**Chronic**	**LM-1**	**BA-1**	**LM-2**	**BA-2**	**LM-3**	**LM-4**	**LM-5**	**LM-6**	**LM-7**	**BA-3**	**LM-8**	**LM-9**	**LM-10**	**REF-1**	**CCREF**
Arsenic	69	36	3.70	3.80	4.80	2.20	2.00	10.40	14.10	17.90	17.90	15.50	11.30	18.50	9.81	1.60	
Barium	na	na	63.90	65.10	160.0	206.0	77.40	110.0	1320.0	407.0	149.0	277.0	93.20	150.0	82.70	22.40	<2.0
Cadmium	43	9.3	0.30	0.60	0.30	0.30	0.30	0.30	1.40	0.50	0.60	0.60	0.60	0.60	0.40	0.70	
Chromium	1100*	50*	4.30	5.10	1.60	9.40	2.30	10.70	5.00	8.40	6.20	5.40	7.00	5.00	8.10	4.50	<2.0
Copper	2.9	2.9	**7.70**	**7.90**	2.60	**6.50**	**5.60**	**15.90**	**10.80**	**25.50**	**10.00**	**9.50**	**17.50**	**10.10**	**8.70**	**29.30**	<10.0
Lead	140	5.6	1.40	<1.00	**22.60**	1.30	2.20	**7.50**	1.30	<1.00	<1.00	<1.00	<1.00	<1.00	1.20	1.40	<1.0
Zinc	95	86	3.20	3.40	2.50	3.60	1.50	4.80	<1.00	2.60	2.50	3.50	3.40	3.00	4.20	2.50	<5.0
TPH	na	na	<100	<100	<100	<100	<100	340.	<100	<100	200	<100	<100	<100	1,090	<100	<5.0

	EPA Marine WQC																
Parameter	**Acute**	**Chronic**	**LM-11**	**LM-12**	**LM-13**	**LM-14**	**LM-15**	**BA-4**	**LM-16**	**BA-5**	**LM-17**	**LM-18**	**LM-19**	**LM-20**	**BA-6**	**REF-2**	
Arsenic	69	36	16.80	4.32	7.06	6.20	6.50	7.60	3.80	9.50	5.50	9.00	8.70	12.30	2.30	4.10	
Barium	na	na	456.00	63.80	106.00	81.30	55.80	52.40	53.50	76.20	72.30	878.00	316.00	35.50	38.30	31.40	
Cadmium	43	9.3	0.20	1.50	0.70	1.40	0.40	1.50	0.60	0.50	1.00	0.60	0.40	0.60	0.50	0.40	
Chromium	1100*	50*	10.60	8.60	9.40	8.30	5.30	6.10	3.10	5.10	5.40	6.10	5.70	4.00	4.60	4.30	
Copper	2.9	2.9	**9.80**	**17.70**	**7.80**	**13.10**	**14.90**	**13.00**	**11.40**	**11.0**	**16.70**	**14.00**	**12.40**	**13.60**	**10.10**	**12.30**	
Lead	140	5.6	2.60	1.40	2.20	1.80	1.30	1.50	<1.00	1.50	2.20	1.90	1.10	1.10	<1.00	<1.00	
Zinc	95	86	3.60	26.50	15.60	1.50	3.50	1.50	4.60	4.80	<1.00	4.40	4.80	2.60	1.10	1.50	
TPH	na	na	<100	<100	<100	<100	1,160	<100	<100	<100	<100	<100	<100	130	<100	<100	

na = no criteria available
Bold type = exceeded criterion

Table 9: Benthic results, Upper Laguna Madre

Number and percentages of surviving organisms

	Replicate (n=5)	True Control	Reference Control 1	Reference Control 2	Mean of Ref. Controls	BA1	BA2	BA3	CCREF Ref Cntrl
				Number of Survivors					
10-DAY SOLID PHASE BIOASSAYS									
A abdita	1	17	13	12		18	10	15	19
20/replicate	2	20	16	11		14	16	16	16
	3	20	9	5		12	18	17	17
	4	16	10	11		17	18	17	18
	5	18	14	12		17	18	18	17
	Average	18 2	12.4	10 2	11 3	15 6	16 0	16 6	17 4
	(%)	91 0%	62 0%	51 0%	56 5%	78 0%	80 0%	83 0%	87 0%
P pugi	1	20	20	19		20	20	20	20
20/replicate	2	20	19	20		20	20	20	20
	3	20	20	20		20	20	20	20
	4	20	20	20		20	20	20	18
	5	20	20	20		20	20	20	20
	Average	20 0	19 8	19 8	19 8	20 0	20 0	20 0	19 6
	(%)	100 0%	99 0%	99 0%	99 0%	100 0%	100 0%	100 0%	98 0%
Total Organisms	1	37	33	31		38	30	35	39
40/replicate	2	40	35	31		34	36	36	36
	3	40	29	25		32	38	37	37
	4	36	30	31		37	38	37	36
	5	38	34	32		37	38	38	37
	Average	38 2	32 2	30	31 1	35 6	36 0	36 6	37
	(%)	95 5%	80 5%	75 0%	77 75%	89 0%	90 0%	91 5%	92 5%
28-DAY BIOACCUMULATION STUDY									
N virens	1	17	13	13		18	10	15	20
20/replicate	2	20	16	16		14	16	16	20
	3	20	9	9		12	18	17	19
	4	16	10	10		17	18	17	20
	5	18	14	14		17	18	18	20
	Average	18 2	12 4	12 4	12 4	15 6	16 0	16 6	19 8
	(%)	91 0%	62 0%	62 0%	62 0%	78 0%	80 0%	83 0%	99 0%
M nasuta	1	20	20	17		20	20	20	17
20/replicate	2	20	19	17		20	20	20	20
	3	20	20	14		20	20	20	10
	4	20	20	22		20	20	20	13
	5	20	20	18		20	20	20	16
	Average	20 0	19 8	17 6	18 7	20 0	20 0	20 0	15 2
	(%)	100 0%	99 0%	70 4%	84 5%	100 0%	100 0%	100 0%	60 8%

Table 10: Benthic results, Lower Laguna Madre

Number and percentages of surviving organisms

	Replicate (n=5)	True Control	Reference Control 1	Reference Control 2	Mean of Ref. Controls	BA4	BA5	BA6
		Number of Survivors						
10-DAY SOLID PHASE BIOASSAYS								
A abdita	1	16	13	12		7	17	7
20/replicate	2	20	16	11		3	5	11
	3	18	9	5		10	10	7
	4	18	10	11		11	11	12
	5	18	14	12		5	11	8
	Average	18 0	12 4	10 2	11 3	7 2	10 8	9 0
	(%)	90 0%	62.0%	51 0%	56 5%	36 0%*	54 0%*	45 0%*
P pugio	1	20	20	19		20	20	20
20/replicate	2	20	19	20		20	20	20
	3	20	20	20		20	20	20
	4	20	20	20		20	20	20
	5	20	20	20		20	20	20
	Average	20.0	19.8	19.8	19 8	20 0	20 0	20.0
	(%)	100 0%	99 0%	99 0%	99 0%	100 0%	100 0%	100 0%
Total Organisms	1	36	33	31		27	37	27
40/replicate	2	40	35	31		23	25	31
	3	38	29	25		30	30	27
	4	38	30	31		31	31	32
	5	38	34	32		25	31	28
	Average	38 0	32 2	30 0	31 1	27 2	30 8	29 0
	(%)	95 0%	80 5%	75 0%	77.75%	68 0%*	77 0%*	72 5%*
28-DAY BIOACCUMULATION STUDY								
N virens	1	17	13	13		18	10	15
20/replicate	2	20	16	16		14	16	16
	3	20	9	9		12	18	17
	4	16	10	10		17	18	17
	5	18	14	14		12	18	18
	Average	18.2	12 4	12 4	12 4	15 6	16 0	16 6
	(%)	91 0%	62 0%	62 0%	62 0%	78 0%	80 0%	83 0%
M nasuta	1	17	20	17		13	13	18
20/replicate	2	20	19	17		20	17	10
	3	15	20	14		5	16	16
	4	14	20	22		14	22	19
	5	14	20	18		9	9	9
	Average	16 0	19 8	17 6	18 7	12 2	16 6	17 0
	(%)	80 0%	99 0%	70 4%	84 7%	48 8%*	66 4%*	68 0%*

*Mean survival less than for reference **Bold face values** = >20% difference in survival between Reference Control and BA station

Table 11: Tissue bioaccumulatıon results, *N vırens*, Upper Laguna Madre

Parameter	Replıcate	True Control	Reference Control 1		Reference Control 2	Station BA-1	BA-2	BA-3	Background	CCREF
Metals (mg/kg)										
Arsenıc	1	1.390	1.220		1 140	0 940	1 140	1.020	1 410	
	2	1 200	1 260		1 100	1.180	1 030	1 090	1 600	
	3	0 980	1 510		1.240	1 000	1 050	0 890	1 420	
	4	1 310	1 220		1.240	0 790	0 840	0 960	1 450	
	5	0.990	1 260		1 530	0 740	1 160	0 650	1 430	
	Total	5 870	6 470	AVG	6 250	4 650	5 220	4.610	7 310	
	Average	1 174	1 294	1.272	1 250	0 930	1 044	0.922	1 462	
	Parameter concentratıon ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are required									
Barıum	1	0 370	0 330		0 290	0 830	0 420	0.610	0 660	1 220
	2	0 350	0 360		0 350	0 380	0.630	0 260	0 780	1 190
	3	0 250	0 270		0 490	0 850	0 410	0 350	0 590	1 080
	4	0 580	0 350		0.460	0 890	0 310	0.230	0 430	0 800
	5	0 300	0 340		0 440	0 520	0 300	0 280	0 750	0 990
	Total	1 850	1 650	AVG	2 030	3.470	2 070	1 730	3 210	5 280
	Average	0 370	0 330	0 368	0 406	**0.694**	**0.414**	0 346	0 642	1 060
	Parameter concentratıon in test tıssues are greater than ın reference tıssues, therefore, statıstıcal analyses of the data are requıred									
Chromıum	1	0 200	0 190		0.140	0 280	0 200	0 220	0 430	0 150
	2	0 170	0 160		0 270	0 130	0 140	0 100	0 440	0 270
	3	0 100	0 110		0 220	1 940	0 140	0 170	0 390	0 280
	4	0.270	0 230		0 140	0.300	0 180	0.120	0.250	0.270
	5	0 130	0 190		0 160	1 250	0 100	0 100	0 350	0 260
	Total	0.870	0.880	AVG	0 930	3.900	0 760	0.710	1 860	1 230
	Average	0 174	0 176	0 181	0 186	**0.780**	0 152	0 142	0 372	0 250
	Parameter concentratıon ın test tıssues are greater than ın reference tıssues, therefore, statıstıcal analyses of the data are requıred									

Bold face values = Test average exceeded Reference Control average

Table 11 (continued)

Parameter	Replicate	True Control	Reference Control 1		Reference Control 2	Station BA-1	BA-2	BA-3	Background	CCREF
Metals (mg/kg)										
Copper	1	2.430	1 330		1.880	2 620	2 050	2 250	2 370	1 910
	2	1 740	3 680		2 110	1 290	1.570	1 780	2 380	3 390
	3	1 540	1 490		2.730	2 950	1 710	1 700	1 760	2 030
	4	1 670	1 250		1.940	2 340	1 640	1 090	1 460	2 630
	5	1 550	2 930		1 630	1 170	1 050	0 970	1 720	2 320
	Total	8 930	10 680	AVG.	10 290	10 370	8 020	7.790	9 690	12 280
	Average	1 786	2 136	2 097	2 058	**2.074**	1 604	1 558	1 938	2 460
	Parameter concentration in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required									
Nickel	1	0 470	0 350		0 220	0 280	0 270	0.250	0 340	0 310
	2	0 360	0 320		0.350	0 110	0 320	0 140	0 290	0 540
	3	0.420	2 440		0 360	0 180	0.250	0 190	0 290	0 730
	4	0 220	0 290		0 320	0 260	0 230	0 140	0 170	0 420
	5	0 310	0 390		0 300	0 380	0 100	0 120	0 250	0 590
	Total	1.780	3 790	AVG.	1 550	1 210	1 170	0 840	1 340	2 590
	Average	0 356	0 758	0 534	0 310	0 242	0 234	0 168	0 268	0 520
	Parameter concentration in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required									
Zinc	1	38 30	9 70		37 90	26 20	20 20	6 91	10 30	9 550
	2	29 00	8 07		38 20	49 70	14 00	21 70	26 30	15 310
	3	15 00	7 24		8.22	10 20	9 49	13 40	11 80	16 780
	4	20 30	7 40		24 30	26 90	34 40	10 40	17 40	19 480
	5	6 55	42 20		14 10	12 50	18 10	6 33	23 50	13 910
	Total	109 15	74 61	AVG	122 72	125 50	96 19	58 74	89 30	75 040
	Average	21 83	14 92	19 73	24 54	**25.10**	19 24	11 75	17 86	15 010
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required									

Bold face values = Test average exceeded Reference Control average

Table 12 Tissue bioaccumulation results, *N. virens*, Lower Laguna Madre

Parameter	Replicate	True Control	Reference Control 1		Reference Control 2	Station BA-4	BA-5	BA-6	Background
Metals (mg/kg)									
Arsenic	1	1 950	1 220		1 140	NA	1 280	1 390	1 590
	2	1 860	1 260		1 100	1 210	1 290	1 280	1 330
	3	1 510	1 510		1.240	1 050	1 560	1 250	1 370
	4	1 170	1 220		1 240	1.360	1 320	0 970	1 400
	5	1 770	1 260		1 530	1 110	1 150	1 090	1 560
	Total	8.260	6 470	AVG	6.250	4 730	6 600	5 980	7 250
	Average	1 652	1 294	1.272	1.250	1.183	**1.320**	1 196	1 450
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required								
Barium	1	0 510	0 330		0.290	NA	0 900	0 630	0 630
	2	0 400	0 360		0 350	0 340	0 450	0 530	0 250
	3	0 620	0.270		0 490	0 630	1 240	0 430	0 300
	4	0.220	0 350		0 460	0 460	0 860	1 430	0 390
	5	0 290	0 340		0 440	0 420	6 690	0 440	0 540
	Total	2 040	1 650	AVG	2 030	1.850	10 140	3 460	2 110
	Average	0 408	0 330	0 368	0 406	**0.463**	**2.028**	**0.692**	0 422
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required								
Chromium	1	0 280	0 190		0 140	NA	0.250	0 260	0 370
	2	0 370	0 160		0.270	0 110	0 210	0 270	0.170
	3	0 230	0 110		0.220	0 240	0 360	0.220	0 240
	4	0 100	0 230		0 140	0 200	0.290	0 290	0 210
	5	0 170	0 190		0 160	0 190	0 210	0 100	0 260
	Total	1 150	0 880	AVG	0 930	0 740	1.320	1.140	1 250
	Average	0 230	0 176	0 181	0 186	**0.185**	**0.264**	**0.228**	0.250
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required								

Bold face values = Test average exceeded Reference Control average

Table 12 (continued)

Parameter	Replicate	True Control	Reference Control 1		Reference Control 2	Station BA-4	BA-5	BA-6	Background
Metals (mg/kg)									
Copper	1	2 310	1 330		1 880	NA	1 710	1 440	2 310
	2	2 500	3.680		2 110	1 130	2 480	2 020	1 740
	3	2 300	1 490		2 730	1 940	1 760	1 940	1 370
	4	0 910	1 250		1 940	2 120	1 500	2 720	1 430
	5	2 490	2 930		1 630	3 330	2 290	1 300	1 460
	Total	10.510	10 680	AVG	10 290	8 520	9 740	9 420	8 310
	Average	2 102	2 136	2 097	2 058	**2.130**	1 948	1 884	1 662
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required								
Nickel	1	0 530	0 350		0.220	NA	0 310	0 410	0 500
	2	0.590	0.320		0.350	0.320	0 270	0 260	0 210
	3	0 620	2 440		0 360	0 340	0 480	1 810	0 250
	4	0.310	0 290		0 320	0 220	0 420	0 330	0 270
	5	0 600	0 390		0 300	0 290	0 290	0 250	0 180
	Total	2 650	3 790	AVG	1.550	1 170	1 770	3 060	1 410
	Average	0 530	0 758	0 534	0 310	0 293	0 354	**0 612**	0 282
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required								
Zinc	1	10 00	9 70		37 90	NA	16 80	15 70	23 00
	2	17 60	8 07		38 20	11 90	7 54	7 39	49 30
	3	22 30	7 24		8 22	25 10	2 76	24 00	11 40
	4	4 48	7 40		24 30	8 17	23 00	6 55	13 90
	5	20 30	42 20		14 10	22 90	8 13	24 40	29 30
Total		74 68	74 61	AVG	122 72	68 07	58 23	78 04	126 90
Average		14 94	14 92	19 733	24 54	17 02	11 65	15 61	25 38
	Parameter concentration in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required								

Bold face values = Test average exceeded Reference Control average

Table 13: Tissue bioaccumulation results, *M nasuta,* Upper Laguna Madre

Parameter	Replicate	True Control	Reference Control 1	BA-1	Station BA-2	BA-3	Background	CCREEF
Metals (mg/kg)								
Arsenic	1	2 480	2 220	1 880	1 820	1 510	2 500	
	2	2 580	2 040	1 920	1.790	1 490	2 500	
	3	2 420	1 940	1 990	1 700	1 090	2 450	
	4	2 440	1 790	2 060	1 430	1 380	2 320	
	5	2 420	2 110	2 050	1 570	1 070	2 480	
	Total	12 340	10 100	9 900	8 310	6 540	12 250	
	Average	2 468	2 020	1 980	1 662	1 308	2 450	
	Parameter concentration in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required							
Barium	1	0 360	1 360	1 730	0 760	0 830	0 610	4.920
	2	0 340	1.580	2.370	1 480	1.100	0.370	5 210
	3	0 580	1 360	1 940	1 820	0 680	0 420	1 920
	4	0 380	2 420	2 700	2 250	0 580	0 400	3 520
	5	0 460	0 870	3 850	2 560	0 760	0 330	0 420
	Total	2 120	7 590	12.590	8 870	3 950	2.130	15 990
	Average	0 424	1 518	**2.518**	**1.774**	0 790	0 426	3 200
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required							
Chromium	1	0 270	0 340	0 100	0 150	0 310	0.270	0 130
	2	0 260	0 450	0 280	0 130	1 770	0 120	0 320
	3	0 230	0 430	0 270	0 190	0 200	0 200	0 270
	4	0 200	0 310	0 210	0 260	0 110	0 130	0 190
	5	3 170	0 340	0 500	0 260	0 150	0 140	0 150
	Total	4 130	1 870	1.360	0 990	2 540	0.860	1 060
	Average	0 826	0 374	0 272	0.198	**0.508**	0 172	0 210
	Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required							

Bold face values = Test average exceeded Reference Control average

Table 13 (contınued)

Parameter	Replıcate	True Control	Reference Control 1	Station BA-1	BA-2	BA-3	Background	CCREF
Metals (mg/kg)								
Copper	1	2 070	3 540	1.130	0 960	3 090	3 030	2 140
	2	4 160	4 640	2 430	1.700	2 090	3 440	3 040
	3	1 300	5 040	1 690	2 100	2 160	1 990	5 930
	4	1 860	3 490	1 690	2 420	1 000	1 600	3 760
	5	1 630	2 540	5 420	2 450	1 650	1 510	2 620
	Total	11 020	19 250	12 360	9 630	9 990	11 570	17 490
	Average	2.204	3 850	2 472	1 926	1 998	2 314	3 500
Parameter concentratıon ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred								
Lead	1	0.100	0 120	0.150	0 100	0 100	0 200	
	2	0 100	0 120	0 180	0 140	0 120	0 200	
	3	0 100	0 180	0 130	0 120	0 110	0 160	
	4	0 110	0 130	0 130	0 140	0 100	0 190	
	5	0 120	0 160	0 180	0 130	0 100	0 200	
	Total	0 530	0 710	0 770	0 630	0 530	0 950	
	Average	0 106	0 142	**0.154**	0 126	0 106	0 190	
Parameter concentratıon ın test tıssues are greater than ın reference tıssues, therefore, statıstıcal analyses of the data are requıred								
Nıckel	1	0 490	0 640	2 550	0 440	0 540	0 460	0 440
	2	0 440	0 670	0 650	0 410	0 470	0 530	0 540
	3	0 520	0 620	0 510	0 470	0 440	0 410	0 390
	4	0 460	0 620	0.610	0 620	0 460	0 480	0 450
	5	0 610	0 570	0 750	0 570	0 590	0 460	0 450
	Total	2 520	3 120	5 070	2 510	2 500	2 340	2 270
	Average	0 504	0 624	**1 014**	0 502	0 500	0 468	0 450
Parameter concentratıon ın test tıssues are greater than ın reference tıssues, therefore, statıstıcal analyses of the data are requıred								
Zınc	1	7 29	11 60	6 43	6 50	8 17	15 00	11 120
	2	7 02	9 51	9 87	8 05	7 89	9 13	11 950
	3	7 54	10 10	9 25	8 85	9 62	9 90	9 890
	4	7 87	8 78	8 87	7 33	7 35	9 70	15 130
	5	7 75	9 00	10 00	7 26	6 82	9 78	10 290
	Total	37 47	48 99	44 42	37 99	39 85	53 51	58 380
	Average	7 49	9 80	8 88	7 60	7 97	10 70	11 680
Parameter concentratıon ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred								

Bold face values = Test average exceeded Reference Control average

Table 14 Tissue bioaccumulation results, *M nasuta*, Lower Laguna Madre

Parameter	Replicate	True Control	Reference Control 1	BA-4	Station BA-5	BA-6	Background
Metals (mg/kg)							
Arsenic	1	1 300	1 200	1 590	1 010	1 870	1 000
	2	1 180	1 160	1 340	0 870	2 010	1 220
	3	1 220	1 520	0 740	1 000	1 820	1 260
	4	1 330	1 440	1 060	1 140	NA	1 340
	5	1:850	2 950	0 900	0 950	1 590	1 550
	Total	6 880	8 270	5 630	4 970	7 290	6 370
	Average	1 376	1 654	1 126	0 994	**1.823**	1.274
	Parameter concentrations in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required						
Barium	1	0 360	1 910	0 400	0 900	1 420	0.220
	2	0 350	3 980	1 090	4 950	2.790	0 220
	3	0 340	4 010	0 300	0 670	3 360	0 230
	4	0 370	2 620	1 280	1 430	NA	0 190
	5	0 480	7 110	0 670	0 780	4 240	0 200
	Total	1 900	19 630	3.740	8 730	11 810	1 060
	Average	0 380	3 926	0 748	1 746	2 953	0 212
	Parameter concentrations in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required						
Cadmium	1	0 100	0 100	0 100	0 100	0 100	0 100
	2	0 100	0 100	0 100	0 100	0.100	0 100
	3	0 100	0 100	0 100	0 100	0 110	0.100
	4	0 100	0 100	0 100	0 100	NA	0.100
	5	0 100	0 120	0 100	0 100	0 100	0 100
	Total	0 500	0 520	0 500	0 500	0 410	0 500
	Average	0 100	0 104	0 100	0 100	0 103	0 100
	Parameter concentrations in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required						

Bold face values = Test average exceeded Reference Control average

Table 14 (contınued)

Parameter	Replicate	True Control	Reference Control 1	BA-4	Station BA-5	BA-6	Background
Metals (mg/kg)							
Chromıum	1	0 270	0 320	0 460	0 590	0 410	0 180
	2	0 180	1 230	0 350	0 230	0 350	0 180
	3	0 350	1 240	0 310	0 510	0 580	1 490
	4	0 570	0 630	0 530	0 220	NA	0 200
	5	0 690	1 540	0 290	0 210	0 780	0 200
	Total	2 060	4 960	1 940	1 760	2 120	2 250
	Average	0 412	0 992	0 388	0 352	0 530	0 450
	Parameter concentratıons ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred						
Copper	1	3 900	2 430	5 420	5 710	3 220	2 620
	2	5 540	8 940	4 300	1 270	2 570	2 630
	3	9 980	9 010	5 430	4 300	3 080	2 050
	4	6 240	6 690	4 280	1 000	NA	2 850
	5	22 400	14 800	1 820	1 260	5 840	2 550
	Total	48 060	41 870	21 250	13 540	14 710	12 700
	Average	9 612	8 374	4 250	2 708	3 678	2 540
	Parameter concentratıons in test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred						
Lead	1	0 100	0 100	0 100	0 100	0 120	0 120
	2	0 100	0 120	0 100	0 100	0 140	0 110
	3	0 100	0 180	0 100	0 100	0 140	0 130
	4	0 100	0 130	0 100	0 100	NA	0 120
	5	0 100	0 330	0 100	0 100	0 120	0 130
	Total	0 500	0 860	0 500	0 500	0 520	0 610
	Average	0 100	0 172	0 100	0 100	0 130	0 122
	Parameter concentratıons ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred						
Nıckel	1	0 690	0 710	0 510	0 670	0 680	0 420
	2	0 580	1 010	0 740	0 600	0 740	0 420
	3	0 610	1 020	0 500	0 590	1 000	0 450
	4	0 780	0 580	0 540	0 670	NA	0 500
	5	1 050	1 570	0 460	0 580	0 680	0 460
	Total	3 710	4 890	2 750	3 110	3 100	2 250
	Average	0 742	0 978	0 550	0 622	0 775	0 450
	Parameter concentratıons ın test tıssues are not greater than ın reference tıssues, therefore, no statıstıcal analyses of the data are requıred						

Table 14 (continued)

Parameter	Replicate	True Control	Reference Control 1	Station BA-4	BA-5	BA-6	Background
Metals (mg/kg)							
Zinc	1	13 30	14 00	12 80	13 30	17 30	12 30
	2	14 70	13 00	15 00	9 76	15 00	14 90
	3	14 90	13 10	6 69	13 90	15 80	15 10
	4	14 60	11 20	9 96	14 80	NA	14,00
	5	14 50	25 90	11 60	13 10	11 70	15 40
	Total	72 00	77 20	56 OS	64 86	59 80	71 70
	Average	14 40	15 44	11 21	12 97	14 95	14 34

Parameter concentrations in test tissues are not greater than in reference tissues, therefore, no statistical analyses of the data are required

Table 15 Summary table of detected analytes per sampling station

Upper Laguna Madre ... Lower Laguna Madre

Analysis	LM 1	BA-1	LM2	BA-2	LM3	LM4	LM5	LM6	LM7	BA-3	LM8	LM9	LM10	REF1	LM11	LM12	LM13	LM14	LM15	BA-4	LM16	BA 5	LM17	LM18	LM19	LM20	BA6	REF2
Sediment - Metals																												
# detected of 10 tested	8	9	9	9	8	8	9	8	8	9	10	8	10	7	8	9	9	7	7	9	8	7	7	7	7	7	10	7
# above guidelines	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	1	0
Water - Metals																												
# above WQC (acute)	1	1	2	1	1	1	1	2	1	2	2	2	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1
Elutriates																												
# above WQC (acute)	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bioassay																												
>20% difference?		n		n						n										y		n					n	
Significant difference?		n		n						n										y		n					n	
Tissue																												
# detected of 10 tested		7		0						0										7		7					7	
# significantly higher		1		0						0										0		2					1	

8. APPENDIX A. SOLID PHASE BIOASSAYS, *A. ABDITA* AND *P. PUGIO*

Table A-1 Range of physical parameters, solid phase bioassays

Upper Laguna Madre

Day	Temperature (^0C)	Salinity ($^0/oo$)	Dissolved O_2 (ppm)	pH
		Ampelisca abdita		
0	20	24	7 6	7 9
1	20	24	7.3 - 7 5	7 9 - 8 2
2	20	25	7.7	7 9
3	20	25	7 4 - 7 5	7 8 - 8 1
4	21	25	7 8	7 8
5	20	25	7 6 - 7 7	7 7 - 7 9
6	21	25	7 8	7 8
7	20	25	7 5 - 7 8	7 8 - 8 0
8	20	25	7 7	7 7
9	20	25	7 4 - 7 6	7 7 - 8 0
10	20	25	7.4 - 7 6	7.6 - 8 0
		Palaeomontes pugio		
0	20	25	7.8	7 3
1	19	25	7 9 - 8 0	7 5 - 7 7
2	20	24	7.7	7 4
3	19	25	7 6 - 7 7	7 8 - 7 9
4	20	24	6 0	8 1
5	19 - 20	26	8 4 - 8 9	7 9 - 8 0
6	21	25	8 7	8 0
7	19	25	7 3 - 7 7	7 9 - 8 2
8	20	26	7 5	7 5
9	19	26	7 6 - 7 8	7 7 - 8 1
10	19	26	7 5 - 7 8	7 8 - 7 9

Table A-1, continued

Lower Laguna Madre

Day	Temperature (^{0}C)	Salinity ($^{0}/oo$)	Dissolved O_2 (ppm)	pH
			Ampelisca abdita	
0	20	24	7 6	7 9
1	20	24	7 3 - 7 5	8.0 - 8.1
2	20	25	7 7	7 9
3	20	25	7 5 - 7.7	8.0 - 8 1
4	21	25	7 8	7.8
5	20	25	7 5 - 7 7	7 9 - 8.2
6	20	25	7 8	7.9
7	20	25	7.4 - 7 7	7 9 - 8 0
8	20	25	7.8	7.9
9	20	25	7.6 - 7.7	7.9 - 8 0
10	20	25	7.5 - 7 8	7 8 - 8 0
			Palaeomontes pugio	
0	20	25	7 8	7 3
1	19	24	7.1	7 6
2	19	25	7 7 - 8.0	8.0 - 8 1
3	20	26	7 6	8 3
4	19	26	7 4 - 7 6	7.7 - 8.0
5	20	24	6.5	8 1
6	19	25	7 6 - 8 2	7 4 - 7 9
7	20	26	8 6	7 4
8	19	24	7 7 - 8 4	7 5 - 7 8
9	19	25	8 2	7 8
10	18	24	7 4 - 7 8	7.7 - 8.0

Table A-2. Statıstical analysıs of *Ampelısca abdıta* survival after 10-day exposure to Lower Laguna Madre sedıments

REPLICATE	REFERENCE	BA4	BA5	BA6
1	12	7	17	7
2	11	3	5	11
3	5	10	10	7
4	11	11	11	12
5	12	5	11	8
6	13			
7	16			
8	9			
9	10			
19	14			
TOTAL	113	36	54	45
MEAN X	11 3	7 2	10 8	9 0
SURVIVAL	55 5	36.0	54.0	45 0

BONFERRONI'S T-TEST

T VALUE	BA4	BA5	BA6
- CALCULATED	2.3143	0 2822	1 2983
- TABULATED	2 2780	2 2780	2.2780
	S	NS	NS

S. DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05
NS· DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

9. APPENDIX B. TISSUE BIOACCUMULATION, *N. VIRENS* AND *M. NASUTA*

Table B-1. Range of physical parameters, bioaccumulation study, Upper Laguna Madre

Day	Temperature (^0C)	Salinity ($^0/_{oo}$)	Dissolved 02 (ppm)	pH
		Nereis virens		
0	20	25	7 4	8 1
1	20	26	4.8 - 7.5	7 6 - 8 2
2	21	26	6 6	8 0
3	20	26	5 9 - 7.5	7 8 - 8 1
4	21	26	7 6	8.1
5	20	26	7 2 - 7 6	7 8 - 8 2
6	21	25	6 4	7 8
7	20	25	7 6 - 7.9	7 9 - 8 1
8	21	27	7 2	8 0
9	19	26	7 1 - 7.5	7 8 - 8 1
10	22	25	6.4	8 1
11	20	26	5 6 - 9 0	7 4 - 8 2
12	21	27	7.7	8.2
13	20	25	7.5 - 7 7	7.8 - 8.0
14	21	25	7 5	7 9
15	20	26	7.2 - 7 3	7 9 - 8 0
16	20	26	6 7	7 9
17	20	26	7.2 - 7 4	7 7 - 8 0
18	20	25	7 3	7 8
19	20	25	8 3 - 8.4	8 1 - 8 2
20	21	25	8 1	8 1
21	19	23	7 2 - 7 4	7.8 - 8 0
22	21	25	6 5	8 0
23	19	23	7 4 - 7 7	7 9 - 8 0
24	21	24	7 2	7 9
25	20	24	7 4 - 7 6	7 7 - 8 0
26	19	25	7 4	7 8
27	20	25	7 7 - 7 9	7 8 - 8 0
28	20	25	7 7	7 8 - 8 0

Table B-1, continued, Upper Laguna Madre

Day	Temperature (^0C)	Salinity ($^0/oo$)	Dissolved 02 (ppm)	pH
		Macoma nasuta		
0	15	25	8.1 - 8.8	7.5 - 7 8
1	14	25	7 9	7.8
2	13	25	8 6 - 8 8	7.5 - 7.8
3	14	25	8 4	7 6
4	12	25	8 6 - 8 7	7 7 - 7 8
5	13	25	8.5	7.7
6	13	25	8.3 - 8.6	7 6 - 7 8
7	15	25	8.0	7.6
8	14	25	8.6 - 8.7	7.7 - 7 8
9	14	25	8 8	7 8
10	15 - 16	24	7.3 - 7.7	7.9 - 8.2
11	16	26	6 6	8 2
12	14	25	8.7 - 9.1	7.8 - 7.9
13	14	24	8.9	7 6
14	14	26	8.9 - 9.1	7.7 - 7.8
15	13	25	8.4	7 8
16	13	25	8.5 - 8.7	7.8
17	14	25	7 9 - 8.2	7 8
18	16	26	8 2 - 8.3	7 8 - 7 9
19	16	25	8.2	7 9
20	14	25	8 9 - 9.2	7 7 - 7 9
21	14	25	8.8	7.9
22	14	25	8 2 - 8 4	7 6 - 7.8
23	14	26	7 8	8.1
24	15	26	9.2 - 9 3	7 7 - 7 8
25	16	26	9 3	7 8
26	15	26	8 9 - 9 0	7.8
27	15	25	8.9	7 8
28	15	25	9 1 - 9 2	7.5 - 7 7

Table B-1, continued, Lower Laguna Madre

Day	Temperature (^0C)	Salinity ($^0/_{oo}$)	Dissolved 02 (ppm)	pH
		Nereis virens		
0	22	25	7 0	8 0
1	21	25	7 5 - 7.7	8 0 - 8 1
2	21	26	6.7	8 0
3	20	26	7 5 - 7 8	7 8 - 7.9
4	20	26	7 3	7 6
5	19	26	7 2 - 8 1	7.7 - 7.8
6	22	26	6 7	8 0
7	20 - 21	25	7 2 - 7 5	7.6 - 7.8
8	22	24	6 8	7.9
9	20	24	7 3 - 7 5	7.5 - 7 9
10	22	26	6 7	8.2
11	20	26	7 5 - 7.7	7.6 - 7 7
12	21	26	7.1	8.0
13	20	26	6 9 - 7.4	7.8 - 7.9
14	21	26	7.2	7.2 - 7.8
15	20	26	8 1 - 8.5	7 9 - 8 0
16	21	26	8 0	8 0
17	21	26	7 2 - 7.5	7 7 - 7 9
18	20	25	7 5	7 9
19	20	23	7 3 - 7 4	7.9 - 8 0
20	22	25	6.3	7 9
21	20	23	8 3 - 8 4	7 8 - 7 9
22	21	24	8 0	7 9
23	20	26	8 1 - 8 2	7 8 - 7 9
24	20	25	8 3	7.8
25	20	26	7 7 - 7 9	8 1 - 8 4
26	21	26	8 0	8 1
27	20	25	7 6 - 7.7	8 0
28	19	25	7 7 - 7 9	7 9 - 8 0

Table B-1, continued, Lower Laguna Madre

Day	Temperature (^0C)	Salinity ($^0/_{oo}$)	Dissolved 02 (ppm)	pH
		Macoma nasuta		
0	15	25	8 3 - 8.9	8 0 - 8 1
1	15	26	8 8	8.1
2	14	25 - 27	8 5 - 8 8	7 8 - 7.9
3	15	26	8 5	8 0
4	14	25	8 6 - 8 9	7.9
5	15	24	7 8	7 9
6	15	26	8 6 - 9.4	7 5 - 7.7
7	14	25	9.0	7 7
8	13	26	8 8 - 9 2	7.4 - 7 7
9	13	25	8 7	7.8
10	13	25	8 8 - 9 1	8.0
11	15	25	8 7	8 0
12	15	27	8.9 - 9.2	7 8 - 7.9
13	15	25	8.7	7 8
14	14	25	8.6 - 9.0	7.6 - 8.0
15	15	25	7.2	8 0
16	14	25	8.2 - 9.0	7.9 - 8 0
17	16	25	8 4	8 0
18	15	25	8 9 - 9 2	7 8 - 7.9
19	17	26	9 2	7 9
20	14	26	9.0 - 9 1	7.8 - 7.9
21	16	25	8 9	7 8
22	14	26	9 0 - 9 1	7.5 - 7 6
23	15	26	9 0	7 8
24	14	26	8 5 - 8 9	7 8
25	15	26	9 0	7 8
26	15	26	8 3 - 8 5	7 8 - 7 9
27	15	26	8 5	7 9
28	15	26	9 7 - 9 8	7 9 - 8 0

Table B-2 Statistical analysis of tissue concentration, barium in *N virens*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0 33	0 83	0 42	0 61
2	0 36	0 38	0 63	0 26
3	0 27	0 85	0 41	0.35
4	0 35	0 89	0.31	0 23
5	0 34	0 52	0 30	0 28
6	0.29			
7	0 35			
8	0 49			
9	0.46			
10	0 44			
TOTAL	3.68	3.47	2.07	1 73
MEAN X	0 368	0 694	0 414	0.346
COEF VAR	19 67	33.03	32.07	44 52

THE VARIANCES ARE HETEROGENEOUS AND TRANSFORMATION WILL NOT HELP

KRUSKAL/WALLIS TEST.

CALCULATED H= 9 193 CRITICAL H= 7 915 df= 3
SINCE CALC H > CRIT H, REJECT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	9 800	7 895	YES
BA-2	1 800	7 895	NO
BA-3	3 600	7 895	NO

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

Table B-2a. Statistical analysis of tissue concentration, barium in *N virens*, archive

REPLICATE	ARCHIVE	BA-1	BA-2	BA-3
1	0 66	0.83	0 42	0 61
2	0.78	0 38	0 63	0 26
3	0 59	0.85	0 41	0 35
4	0 43	0 89	0.31	0 23
5	0.75	0 52	0 30	0 28
6	0 63			
7	0 25			
8	0.30			
9	0 39			
10	0 54			
TOTAL	5.32	3.47	2.07	1 73
MEAN X	0 532	0 694	0 414	0 346
COEF VAR	- 34 45	33 03	32.07	44 52

BONFERRONI' S T-TEST

T VALUE	BA-1	BA-2	BA-3
- CALCULATED	1 6462	1.1991	1.8900
- TABULATED	2.2780	2 2780	2 2780
	NS	NS	NS

S DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05

NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

Table B-3 Statistical analysis of tissue concentration, chromium in *N virens*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0 19	0 28	0 20	0 22
2	0 16	0 13	0 14	0 10
3	0 11	1 94	0 14	0.17
4	0 23	0 30	0 18	0 12
5	0 19	1 25	0 10	0 10
6	0 14			
7	0 27			
8	0 22			
9	0 14			
10	0 16			
TOTAL	1.81	3 90	0 76	0 71
MEAN X	0 181	0.780	0 152	0 142
COEF VAR	26 87	100 73	25 65	36.73

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP

KRUSKAL/WALLIS TEST.

CALCULATED H= 7.658 CRITICAL H= 7 915 df= 3

SINCE CALC H <= CRIT H, ACCEPT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0.05

Table B-3a Statistical analysis of tissue concentration, chromium in *N virens*, archive

REPLICATE	ARCHIVE	BA-1	BA-2	BA-3
1	0 43	0 28	0 20	0 22
2	0 44	0 13	0 14	0 10
3	0 39	1 94	0 14	0 17
4	0 25	0.30	0.18	0 12
5	0 35	1 25	0 10	0 10
6	0 37			
7	0 17			
'8	0 24			
9	0 21			
10	0 26			
TOTAL	3 11	3 90	0.76	0 71
MEAN X	0 311	0 780	0 152	0 142
COEF VAR	30 97	100 73	25 65	36 73

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP

THE KRUSKAL/WALLIS TEST

CALCULATED H 12 943 CRITICAL H= 7 915 df= 3

SINCE CALC H > CRIT H, REJECT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0 05. SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	0 750	7 892	NO
BA-2	9 850	7 892	YES
BA-3	11.150	7 892	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

Table B-4 Statistical analysis of tissue concentration, zinc in *N virens*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	9 70	26 20	20 20	6 91
2	8.07	49 70	14 00	21 70
3	7 24	10.20	9 49	13 40
4	7 50	26 90	34 40	10 40
5	42 20	12 50	18 10	6 33
6	37 90			
7	38 20			
8	8 22			
9	24 30			
10	14 10			
TOTAL	197.43	125.50	96 19	58 74
MEAN X	19.743	25.100	19 238	11 748
COEF VAR	73 66	62 69	48 94	53 22

BONFERRONI' S T-TEST

T VALUE			
- CALCULATED	0 7681	0 0724	1 1464
- TABULATED	2 2780	2.2780	2 2780
	NS	NS	NS

S · DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

Table B-5 Statistical analysis of tissue concentration, arsenic in *N virens*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1 14	1 21	1 28	1 39
2	1 10	1.05	1.29	1 28
3	1 24	1 36	1 56	1 25
4	1 24	1 11	1 32	0 97
5	1 53		1 15	1 09
.6	1 14			
7	1.10			
8	1 24			
9	1 24			
10	1.53			
TOTAL	12 50	4.73	6 60	5 98
MEAN X	1 250	1 183	1 320	1 196
COEF VAR	12.69	11 46	11 30	13.86

BONFERRONI' S T-TEST

T VALUE	BA-4	BA-5	BA-6
- CALCULATED	0.7362	0 8246	0.6361
- TABULATED	2.2060	2.2060	2.2060
	NS	NS	NS

S . DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

Table B-6 Statistical analysis of tissue concentration, barium in *N virens*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0 33	0 34	0 90	0.63
2	0 36	0 63	0.45	0 53
3	0 27	0 46	1 24	0.43
4	0 35	0 42	0 86	1 43
5	0 34		6 69	0.44
6	0 29			
7	0 35			
8	0.49			
9	0 46			
10	0 44			
TOTAL	3 68	1.85	10.14	3 46
MEAN X	0 368	0 463	2 028	0 692
COEF VAR	19 67	26 44	129 25	60 75

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

KRUSKAL/WALLIS TEST

CALCULATED H= 12.242 CRITICAL H= 7 915
df= 3
SINCE CALC H > CRIT H, REJECT Ho. ALL GROUPS ARE EQUAL AT ALPHA = 0 05

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-4	4 275	8 190	NO
BA-5	12 650	7 583	YES
BA-6	8 650	7 583	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

Table B-6a Statistical analysis of tissue concentration, barium in *N virens*, archive

REPLICATE	ARCHIVE	BA-4	BA-5	BA-6
1	0 66		0 90	0 63
2	0.78	0 34	0 45	0.53
3	0.59	0 63	1 24	0 43
4	0 43	0 46	0.86	1 43
5	0 75	0.42	6 69	0 44
6	0.63			
7	0.25			
8	0.30			
9	0 39			
10	0 54			
TOTAL	5.32	1.85	10.14	3 46
MEAN X	0 532	0.463	2 028	0 692
COEF VAR	34 45	26.44	129 25	60 75

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

KRUSKAL/WALLIS TEST

CALCULATED H= 6.565 CRITICAL H= 7.915 df= 3

SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

Table B-7 Statistical analysis of tissue concentration, chromium in *N virens*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0.19	0 11	0 25	0 26
2	0 16	0 24	0 21	0 27
3	0 11	0 20	0 36	0.22
4	0 23	0.19	0.29	0 29
5	0 19		0 21	0 10
6	0.14			
7	0.27			
8	0 22			
9	0.14			
10	0.16			
TOTAL	1 81	0 74	1.32	1 14
MEAN X	0 181	0.185	0 264	0.228
COEF VAR	26 87	29.44	23.90	33 32

BONFERRONI' S T-TEST

	BA-4	BA-5	BA-6
T VALUE			
- CALCULATED	0.1150	2 5764	1.4589
- TABULATED	2.2060	2.2060	2.2060
	NS	S	NS

S : DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05

NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

Table B-7a Statistical analysis of tissue concentration, chromium in *N virens*, archive

REPLICATE	ARCHIVE	BA-4	BA-5	BA-6
1	0 43		0 25	0.26
2	0 44	0 11	0 21	0 27
3	0 39	0 24	0.36	0 22
4	0 25	0 20	0 29	0 29
S	0 35	0.19	0 21	0 10
6	0 37			
7	0 17			
8	0 24			
9	0 21			
10	0 26			
TOTAL	3 11	0 74	1 32	1 14
MEAN X	0.311	0 185	0.264	0.228
COEF VAR	30 97	29.44	23 90	33.32

BONFERRONI' S T-TEST

T VALUE			
- CALCULATED	2 6277	1 0587	1.8696
- TABULATED	2 2060	2 2060	2 2060
	S	NS	NS

S : DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS . DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

Table B-8 Statıstıcal analysıs of tıssue concentratıon, copper in *N vırens*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1.33	1 13	1 71	1 44
2	3 68	1 94	2 48	2 02
3	1 49	2 12	1.76	1 94
4	1 25	3 33	1 50	2 72
S	2 93		2 29	1 30
'6	1 88			
7	2 11			
8	2 73			
9	1.94			
10	1 63			
TOTAL	20.97	8.52	9 74	9 42
MEAN X	2 097	2 130	1 948	1.884
COEF VAR	37 50	42 65	21.36	29 78

BONFERRONI' S T-TEST

	BA-4	BA-5	BA-6
T VALUE			
- CALCULATED	0.0789	0 3849	0.5502
- TABULATED	2 2060	2 2060	2.2060
	NS	NS	NS

S · DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

Table B-9. Statistical analysis of tissue concentration, nickel in *N virens*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0.35	0.32	0.31	0 41
2	0 32	0 34	0 27	0 26
3	2 44	0 22	0.48	1 81
4	0.29	0 29	0 42	0 33
S	0 39		0.29	0 25
6	0 22			
7	0.3S			
8	0 36			
9	0 32			
10	0 30			
TOTAL	5 34	1 17	1.77	3 06
MEAN X	0.534	0 292	0 354	0.612
COEF VAR	125.72	17.96	25 78	109 93

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

KRUSKAL/WALLIS TEST.

CALCULATED H= 1.311 CRITICAL H= 7.915 df= 3
SINCE CALC H <= CRIT H, ACCEPT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

Table B-10. Statistical analysis of tissue concentration, barium in *M. nasuta*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	1 36	1.73	0 76	0.83
2	1 58	2 37	1 48	1 10
3	1.36	1.94	1.82	0 68
4	2 42	2.70	2 25	0.58
5	0 87	3.85	2 56	0 76
TOTAL	7.59	12.59	8 87	3.95
MEAN X	1 518	2 518	1.774	0 790
COEF VAR	37.37	33 13	39.47	24.90

THE LN X+1 TRANSFORM WILL BE USED FOR STATISTICAL ANALYSIS. LN X+1 COEFFICIENTS OF VARIATION

COEF VAR	24 07	18.16	27 75	18.52

	DF	SUM SQUARES	MEAN SQUARE	F-CALC
TREATMENTS	3	1.115	0 372	8 032
ERROR	16	0 740	0 046	
F-TABULATED				3.240

SINCE F-CALCULATED > F-TABULATED, THE DIFFERENCE AMONG THE MEANS IS SIGNIFICANT AT P=0.05 AND THE DUNNETTS COMPARISON WILL BE PERFORMED

MEAN COMPARISONS

DIFFERENCE IN MEANS

BA-1 VS REFERENCE	
1.237 - 0.904 = 0 333	SIGNIFICANT
BA-2 VS REFERENCE	
0 992 - 0 904 = 0 088	NOT SIGNIFICANT
REFERENCE VS BA-3	
0.904 - 0.578 = 0 327	SIGNIFICANT

THE MINIMUM DETECTABLE DIFFERENCE = 0 30
DUNNETTS CRITICAL VALUE = 2 23

Table B-11 Statistical analysis of tissue concentration, chromium in *M nasuta*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0 34	0 10	0 15	0.31
2	0 45	0 28	0.13	1.77
3	0.43	0.27	0.19	0 20
4	0 31	0.21	0.26	0.11
S	0 34	0.50	0 26	0.15
TOTAL	1 87	1.36	0.99	2.54
MEAN X	0 374	0 272	0 198	0 508
COEF VAR	16 55	53.74	30 60	139 66

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

KRUSKAL/WALLIS TEST.

CALCULATED H= 6 657 CRITICAL H= 7 915 df= 3

SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05

Table B-12 Statistical analysis of tissue concentration, nickel in *M nasuta*, reference

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0.64	2 55	0 44	0 54
2	0 67	0 65	0 41	0 47
3	0 62	0 51	0 47	0.44
4	0 62	0 51	0 62	0 46
5	0 57	0 75	0 57	0 59
TOTAL	3 12	4.97	2.51	2 50
MEAN X	0 624	1 014	0 502	0 50
COEF VAR	5.84	88 10	17 78	12.57

THE DATA ARE NOT NORMALLY DISTRIBUTED AND

TRANSFORMATION WILL NOT HELP

KRUSKAL/WALLIS TEST

CALCULATED H= 8 528 CRITICAL H= 7.915 df= 3

SINCE CALC H > CRIT H, REJ3ECT Ho: ALL GROUPS ARE EQUAL AT

ALPHA = 0 05. SINCE Ho IS REJECTED, THE DUNN MULTIPLE

COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	0 300	7 312	NO
BA-2	7 800	7 312	YES
BA-3	7 900	7 312	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

Table B-13 Statistical analysis of tissue concentration, arsenic in *M nasuta*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1 20	1 59	1 01	1.87
2	1.16	1.34	0 87	2 01
3	1 52	0 74	1.00	1 82
4	1 44	1 06	1.14	1.59
5	2.95	0.90	0 95	0 00
TOTAL	8 27	5 63	4.97	7 29
MEAN X	1 654	1 126	0 994	1 823
COEF VAR	44.77	30.30	9 92	9 58

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP

KRUSKAL/WALLIS TEST

CALCULATED H= 11.309 CRITICAL H= 7 915
df= 3

SINCE CALC H > CRIT H, REJECT Ho· ALL GROUPS ARE EQUAL AT ALPHA = 0.05

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-4	5 300	6 973	NO
BA-5	7 600	6 973	YES
BA-6	3 775	7.396	NO

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

Table B-14. Statistical analysis of tissue concentration, lead in *M. nasuta*, reference

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0 12	0 15	0.10	0.10
2	0 12	0.18	0 14	0 12
3	0 18	0 13	0 12	0 11
4	0.13	0 13	0 14	0 10
5	0.16	0 18	0.13	0.10
TOTAL	0 71	0 77	0 63	0.53
MEAN X	0 142	1 126	0 126	0 106
COEF VAR	18 90	30 30	13 28	8.44

	DF	SUM SQUARES	MEAN SQUARE	F-CALC
TREATMENTS	3	0.006	0.002	5 053
ERROR	16	0.007	0 000	
F-TABULATED				3 240

SINCE F-CALCULATED > F-TABULATED, THE DIFFERENCE AMONG THE MEANS IS SIGNIFICANT AT P=0 05 AND THE DUNNETTS COMPARISON WILL BE PERFORMED

MEAN COMPARISONS

DIFFERENCE IN MEANS

BA-1 VS REFERENCE	
0.154 - 01.42 = 0.012	NOT SIGNIFICANT
REFERENCE VS BA-2	
0.142 - 0 904 = 0 088	NOT SIGNIFICANT
REFERENCE VS BA-3	
0.142 - 0 106 = 0 036	SIGNIFICANT

THE MINIMUM DETECTABLE DIFFERENCE = 0 03

DUNNETTS CRITICAL VALUE = 2 23

10. QUALITY ASSURANCE PROJECT PLAN

The Quality Assurance Project Plan (QAPP) was previously submitted and approved It is included as a separately bound attachment to this Characterization Report.